

Game on R&D Between Producer Service and Manufacturing Industry: A Research Based on Technological Interrelatedness

Yuan Yijun¹, Du Lili^{1,2}, Geng Dianhe¹

¹ Department of Economics, Dalian University of Technology, Dalian, Liaoning, P.R. China, 116024

² International College, Dalian University, Dalian, Liaoning, P.R. China, 116622

(E-mail: yjyuan@dlut.edu.cn, dulili@dlu.edu.cn, gengdianhe@163.com)

Abstract This paper concerns itself with the rationale of the outsourcing business of manufacturing industry forming producer service industry, explores the technological relationship between two industries, and analyzes their R&D strategies through game theory approach. Under weak degree of technological interrelatedness, their technique R&D would construct mixed Nash equilibrium on certain probability, which leads to R&D synergetic innovation effects; under strong degree of technological interrelatedness, manufacturing and producer service industry take R&D first-mover and follower role respectively, which forms R&D game Nash equilibrium. The ending part considers the R&D game demonstration of two industries under different degree of technological interrelatedness. These final thoughts bring into the conclusions.

Keywords Technological interrelatedness; Synergetic innovation; Producer services industry; Technology R&D first-mover

1 Introduction

With the pattern of economic growth changing, economic structure has been continuously readjusting and upgrading. Characterized by huge potential of value creating and vocation employing, modern producer service industry has dramatically promoted the development of manufacturing industry. Home and broad academic research shows ^{[1] [2] [4]} that the relationship between service and manufacturing industry performs not simply causal, but constant interacting under technological interrelatedness situation. The current research, which examines the internal interacting mechanism of technology innovation and R&D of two industries, is still unsatisfying. This paper starts with the technological interrelatedness between manufacturing and producer service industry, exploring their synergetic innovation mechanism under weak degree of technological interrelatedness, and the impact of technology R&D strategy of manufacturing industry on that of producer service industry under strong degree technological interrelatedness. New clues and approaches being brought into in this paper to analyze the technology innovation and R&D interactive relationship between manufacturing and producer service industry, which would provide the academic bases to drive the technology innovation and R&D of both industries.

2 Definition of Technological Interrelatedness

2.1 Concept of technological interrelatedness

Proceeds from technology systematicness and the function information technology, (Freeman and Soete 2004) explored the relevance of technology system, and its significance to developing countries. They pointed out that development does not merely mean the success of one typical product, but the technology system established during the process of developing and evolving, which consequently achieve potential sustainable development. (Frankel 1995) analyzed the technological interrelatedness issue for the first time in his article Technology Backward and Evolving in Mature Economy, published on The American Economic Review. While the discussion focused mainly on the hinder of technological interrelatedness to structure upgrading and adjusting, with no respect to take technological interrelatedness to strengthen the technology innovation.

This paper begins with business operational mechanism, tries to build up the concept of technological interrelatedness through the analysis of relative business technology activities. The so-called technological interrelatedness means the interactional, mutually complementary relevance among various industries in production process. It embodies (1) Among industries with technological interrelatedness, the technology innovation of one typical business needs the support of technology innovation from other related businesses. (2) The revenue of one typical business with technology

innovation would motivate the technology innovation investment of related businesses. (3) Technology innovation of one business would have tremendous implication and promotion effects on other related businesses. (4) Technology spread and technological interrelatedness constitute the technology innovation spread net, which would form the synergetic innovation of related industries and promote the technology innovation capacity of industry chain.

2.2 Technological interrelatedness between producer service and manufacturing industry

Producer service industry renders manufacturing industry as follows^[3], consequently forms strong technology relevance. (1) Directly, the products and services provide by producer service industry are taken as the intermediate input. (2) Certain part of currency and financial service in the process of merchant exchange. (3) Services needed by the formation of human capital that goes with new productive structure, like training agency. (4) Services needed to spatially coordinate and regulate productive system as a whole. In the process of value creation, labor division of producer service and manufacturing industry form the technological interrelatedness, this is the essential building block of their interaction. More departments, originally internal based, find them separated from manufacturing industry in the wake of deepening modern labor division. The new formed service industry has amply intensified the technological interrelatedness.

The weak or strong degree of technological interrelatedness between producer service and manufacturing industry varies to the vicarism of goods or services supplied by producer service industry. The more important the goods or services supplied by producer service industry to the productive operation activities of manufacturing industry with less congener goods or services, the stronger degree of technological interrelatedness between them. Besides, technological interrelatedness degree depends on the specialization of producer service industry as well, the higher the goods or services specialization needed by productive operation activities of manufacturing industry, the stronger degree of technological interrelatedness between them.

3 Game on R&D Between Producer Service and Manufacturing Industry on Technological Interrelatedness

Due to technological interrelatedness between producer service and manufacturing industry, the surplus profits gained from technology R&D of their businesses are closely related, on which directly influence their R&D strategy. The cost input and revenue of R&D characterized by certainty and uncertainty respectively. That is to say, the successful or failing results of R&D hinge on probability. Normally, the probability of success goes higher as more R&D cost input. Assume the R&D cost of producer service industry is C_{s0} , the probability of R&D success is P_s , R&D revenue is R_{s0} , the predict profit is π_s , only when the predict revenue larger than R&D cost, that is $\pi_s = P_s R_{s0} - C_{s0} > 0$, the R&D would be carried on. Equally to manufacturing industry, assume the R&D cost is C_{m0} , the probability of R&D success is P_m , R&D revenue is R_{m0} . Same as the conditions of producer service industry, only when the predict profit larger than zero, meaning $\pi_m > 0$, the R&D would be carried on, that is $\pi_m = P_m R_{m0} - C_{m0} > 0$.

The technological interrelatedness between producer service and manufacturing industry differs with respect to various industry types, the weak or strong degree of technological interrelatedness would affect the revenue gained from technique R&D strategy of producer service and manufacturing industry. Indeed, both industries would determine their technique R&D strategy with reference to the weak or strong degree of technological interrelatedness.

3.1 R&D game between producer service and manufacturing industry under strong degree of technological interrelatedness

The strong degree of technological interrelatedness influence the profits of technique R&D of producer service and manufacturing industry, we particularly sharpen our attention on the impact of manufacturing industry R&D have on producer service industry. Producer service and manufacturing industry would take R&D strategy portfolio: firstly, the so-called R&D first-mover, that is, they process R&D at the same time. Secondly, one of them takes R&D in advance, the other gains additional profits by taking maximum advantage of later R&D through technological interrelatedness and information sharing. Thirdly, both of them refuse to process R&D in advance; R&D profit under this situation is zero.

Suppose both of the industries adopt first- mover strategy, the additional R&D profits

are π_s^* and π_m^* respectively; if producer service industry acts as first-mover, it would gains R&D profit π_s' , as the follower, the R&D profit of manufacturing industry is π_{m0} . Accordingly, if producer service industry acts as follower, it would gains R&D profit π_{s0} , as the first-mover, the R&D profit of manufacturing industry is π_m' . When both of them choose to be R&D follower, their R&D profit is π_s^0 and π_m^0 respectively. Therefore, their R&D game illustrates as figure 1:

		Producer Service Industry	
		First-mover	Follower
Manufacturing Industry	First-mover	π_m^*, π_s^*	π_m', π_{s0}
	Follower	π_{m0}, π_s'	π_m^0, π_s^0

Figure 1 R&D Game Between Producer Service and Manufacturing Industry under Strong Degree of Technological Interrelatedness

Act as first-mover; manufacturing industry motivates the follower, producer service industry to process technique R&D activities through price increasing. The greater profits from which the technique R&D of producer service industry can achieve depends heavily on the information sharing and technological interrelatedness. If, similarly, producer service industry chooses first-mover role, the technology level of two industries would determine the R&D profit results, neither of them would take any R&D advantage of the other part through technological interrelatedness. When taking first-mover role, due to the huge R&D costs and uncertainty, producer service industry may suffer more risks and fall into big profit loss. Meanwhile, as the follower, manufacturing industry would take maximum advantage of the information and convenience of producer service industry to conduct its R&D apace and gain more profits. Therefore, the profit relationship under different R&D strategies of producer service industry is $\pi_{s0} > \pi_s^* > \pi_s^0 > \pi_s'$, accordingly, the profit relationship under different R&D strategies of manufacturing industry is $\pi_{m0} > \pi_m^* > \pi_m' > \pi_m^0$.

During game, because of $\pi_s^* < \pi_{s0}$ and $\pi_s' < \pi_s^0$, that is, whether manufacturing industry chooses R&D first-mover or follower, the profits of producer service industry gained as R&D follower would be larger than that as R&D first-mover. To producer service industry, therefore, technique R&D first-mover is a strictly unwise decision. In any case, producer service industry would act as follower other than first-mover. When producer service industry takes follower role, because of $\pi_m' > \pi_m^0$, manufacturing industry would choose first-mover role for R&D profits. Hence, under the strong degree of technological interrelatedness, the strategic portfolio (manufacturing: first-mover, producer service industry: follower) achieves R&D game Nash equilibrium.

Under strong degree of technological interrelatedness, act as R&D and innovation sponsor and pusher, manufacturing industry takes its technology innovation advantage to promote itself and the technology improvement and innovation of strong technological interrelated producer service industry. Thereby, the interrelatedness effects demonstrating technique R&D of manufacturing industry drives technology upgrading of producer service industry unfold.

3.2 R&D game between producer service and manufacturing industry under weak degree of technological interrelatedness

As we shall see, under weak degree of technological interrelatedness, because of information sharing, technology leading and profit redistribution, any part as first-mover would become the leading driver to the other part that would benefits from high probability of technique R&D success. Like strong degree of technological interrelatedness, producer service and manufacturing industry take first-mover

or follower strategy in R&D game as well, they differ in terms of various strategic portfolio. Figure 2 illustrates R&D game between producer service and manufacturing industry:

		Productive service Industry	
		First-mover	Follower
Manufacturing Industry	First-mover	π_m^*, π_s^*	π_m', π_{s0}
	Follower	π_{m0}, π_s'	π_m^0, π_s^0

Figure 2 R&D Game Between Producer Service and Manufacturing Industry under Weak Degree of Technological Interrelatedness

When both producer service and manufacturing industry act as R&D follower, neither of them would conduct technique R&D forwardly, their R&D profit is zero, that is $\pi_m^0 = \pi_s^0 = 0$. If both of them take first-mover role, they would benefit during R&D process. Because of weak degree of technological interrelatedness, two industries conduct R&D exclusively, which affects profit more slightly. If one part takes first-mover role and the other acts as follower, the follower who gets information and technology support would get technological interrelatedness-based R&D advantage and gain greater profit. To producer service industry, profit relationship of different R&D strategy is $\pi_{s0} > \pi_s^* > \pi_s' > \pi_s^0$ ($\pi_s^0 = 0$); profit relationship of different R&D strategy of manufacturing industry is $\pi_{m0} > \pi_m^* > \pi_m' > \pi_m^0$ ($\pi_m^0 = 0$).

Here we use the mixed strategic game, not pure Nash equilibrium. According to Nash equilibrium principle, suppose the probability of the first-mover, producer service industry is $P_s(C)$, probability of its follower choice is $P_s(D)$, then whether manufacturing industry chooses first-mover or follower; it gains equal expect R&D profit.

$$\begin{cases} P_s(C)\pi_m^* + P_s(D)\pi_m' = P_s(C)\pi_{m0} + P_s(D)\pi_m^0 \\ P_s(C) + P_s(D) = 1 \\ \pi_m^0 = 0 \end{cases} \quad (1)$$

We may get Nash equilibrium $P_s(C)^* = \frac{\pi_m'}{\pi_m' - \pi_m^* + \pi_{m0}}$, $P_s(D)^* = \frac{\pi_m^* - \pi_{m0}}{\pi_m^* - \pi_{m0} - \pi_m'}$.

To manufacturing industry, suppose the probability of first-mover role is $P_m(A)$, the probability of follower choice is $P_m(B)$, then whether producer service industry chooses first-mover or follower; it gains equal expect R&D profit.

$$\begin{cases} P_m(A)\pi_s^* + P_m(B)\pi_s' = P_m(A)\pi_{s0} + P_m(B)\pi_s^0 \\ P_m(A) + P_m(B) = 1 \\ \pi_s^0 = 0 \end{cases} \quad (2)$$

The mixed strategy of game is $P_m(A)^* = \frac{\pi_s'}{\pi_s' - \pi_s^* + \pi_{s0}}$, $P_m(B)^* = \frac{\pi_s^* - \pi_{s0}}{\pi_s^* - \pi_{s0} - \pi_s'}$.

When producer service industry adopts technology R&D first-mover and follower in terms of the probability distribution of $(P_s(C)^*, P_s(D)^*)$, while manufacturing industry adopts technology R&D

first-mover and follower in terms of the probability distribution of $(P_m(A)^*, P_m(B)^*)$, neither part of the game can increase R&D profits through strategy changing, that is, solely changes the probability distribution of pure random strategy. Therefore, the above probability distribution portfolio compromises a mixed strategic Nash equilibrium.

4 Synergetic Innovation Between Producer Service and Manufacturing Industry under Weak Degree of Technological Interrelatedness

The so-called synergetic innovation is the technology innovation-diffusing network formed by internal technology innovation diffusion and technological interrelatedness among industries, it shows the process of technology upgrading of the industry chain as a whole. We refers to internal technology diffusion as the process other firms imitate and learn the technology innovation activities of an inside typical firm. Technological interrelatedness among industries means the technology innovation of one firm will prevail as the technology-driven to other firms. Before fully separating from manufacturing industry, producer service industry subordinates to manufacturing industry as a typical department or link. The inside technological interrelatedness of the firm still exists even after labor division (producer service industry separates from manufacturing industry chain), which becomes fundamental base of their mutual technology innovation influence and motivation, and hinges on these essential building blocks of their synergetic innovation.

According to different strategy profit relationship of producer service and manufacturing industry $\pi_{s0} > \pi_s^* > \pi_s' > \pi_s^0$ ($\pi_s^0 = 0$) and $\pi_{m0} > \pi_m^* > \pi_m' > \pi_m^0$ ($\pi_m^0 = 0$), we may get the probability relationship when producer service and manufacturing industry take R&D first-mover and follower:

To producer service industry, we have $P_s(C)^* > P_s(D)^*$, that is $\frac{\pi_s'}{\pi_s - \pi_s^* + \pi_{s0}} > \frac{\pi_s^* - \pi_{s0}}{\pi_s^* - \pi_{s0} - \pi_s'}$; to manufacturing industry, we have $P_m(A)^* > P_m(B)^*$, that is $\frac{\pi_m'}{\pi_m - \pi_m^* + \pi_{m0}} > \frac{\pi_m^* - \pi_{m0}}{\pi_m^* - \pi_{m0} - \pi_m'}$. The probability that both producer service and manufacturing industry take first-mover is larger than that of the follower role. The first-mover role taken by both of the two industries forms the new synergetic innovation effects.

The following figure illustrates the synergetic innovation rational of producer service and manufacturing industry under weak degree of technological interrelatedness:

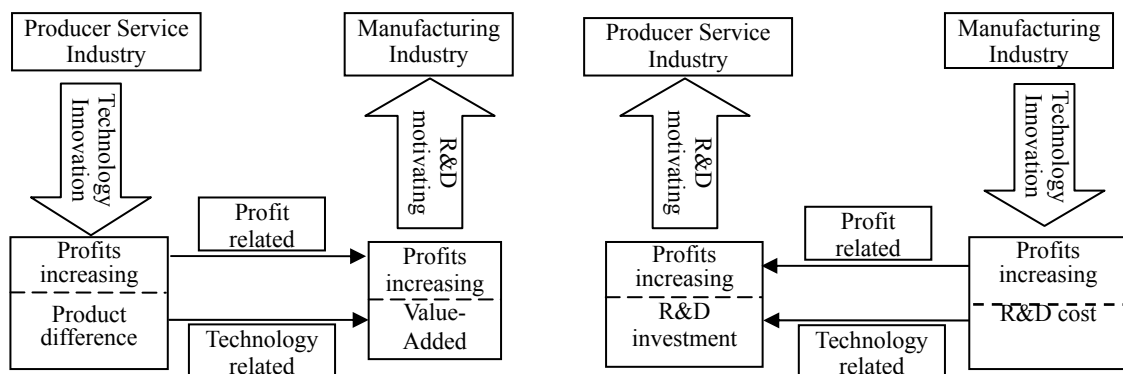


Figure 3 Mutual Influence Between Producer Service and Manufacturing Industry

The technology innovation of manufacturing industry drives and affects the technology innovation of producer service industry through innovation revenue and R&D cost. Technology innovation of manufacturing industry needs services and supports, even the simultaneous upgrading provided by firms of producer service industry. Manufacturing industry, therefore, must sacrifice part of R&D revenue to guarantee higher service cost, which motivates producer service industry conducting technological innovation. Ultimately, the degree of technological interrelatedness between these two industries

determines the results of revenue motivation effects. The higher degree of technological interrelatedness would drive larger R&D revenue gaining by producer service industry.

Technology innovation revenue and manufacturing products value-added reflect the important role of producer service industry in terms of technology progress and standard upgrading. With respect to technology innovation revenue, producer service industry pursues its own benefits, reduces producing cost and improves service through R&D and innovation, thereby, provides quality service for manufacturing industry with lower price. Manufacturing industry, in general, would focus on technology innovation and R&D with more capital and efforts. Technology innovation of producer service industry acts as available driver, but not essential reason to the technology innovation of manufacturing industry. Concerning with manufacturing product value, the new otherness products embodies the special technology provided by producer service industry, like technology innovation and R&D design, which implement the value-adding process. Manufacturing industry can take value-added revenue as R&D investment, and consequently achieves the process of producer service industry driving manufacturing industry upgrading.

5 Conclusions

The analysis of R&D strategy and profits between producer service and manufacturing industry under different degree of technological interrelatedness provides not only the academic rationale building blocks for examining producer service industry as upgrading-driven to manufacturing industry, but the valuable reference to regulate relevant policies—not all producer service industry fit for first-mover role.

From firm point of view, under strong degree of technological interrelatedness, producer service industry would almost lose R&D motivation with no need of new technology from manufacturing industry. Therefore, the better role for producer service industry is R&D follower that hinges closely on R&D orientation of manufacturing industry. By taking advantage of the convenience of R&D information and profits from manufacturing industry, the innovation activities of producer service industry would easily unfold. Under weak degree of technological interrelatedness, by means of mutual innovation motivation, producer service industry should take first-mover strategy and collaborate with manufacturing industry, to keep its mighty competitor role and achieve win-win situation through technology union with manufacturing industry. Whatever degree of technological interrelatedness, to manufacturing industry, the continuous technology R&D and innovation is the major path to gain a foothold in product market share, and maintain core competition.

From government point of view, during industry structural upgrading, producer service industry developing, and manufacturing industry technology improving process, their exclusive technology innovation should not be given too much emphasis. Indeed, government should regulate technology innovation strategy and policy with reference to different degree of technological interrelatedness for two industries. Under strong degree of technological interrelatedness, government should guide and promote the technology innovation and upgrading of manufacturing industry; build free innovation environment, and construct effective information and technology transmission mechanism for them. Producer service industry may precisely know and grasp the R&D trend of manufacturing industry in time, and explore its own innovation strategy and R&D path more effectively with less uncertainty. Under weak degree of technological interrelatedness, due to their synergetic innovation effect, government should bridge producer service and manufacturing industry through technology R&D communication platform and facilitate technology union, expand technology communication and R&D collaboration between two industries.

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