Technology Transfer, Technology Gap and Technology Spillover: a Dynamic Model

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Abstract—With the development of foreign trade, foreign direct investment (FDI) has become an important channel of technology transfer and been a great impetus to the technological innovation of the host country. This paper aims to explore the influence of factors of host-country on technology transfer of multinational corporations (MNCs) by developing a dynamic model. The results show that the relationship between technology gap and technology spillover is uncertain; The imitative capability and learning efficiency of local firm is negatively related to technology transfer speed; Product substitutability is positively related to technology transfer level. Some practical cases are provided to verify these propositions. And the significance of the results is further revealed in conclusions by comparing with Wang and Blomstrom's classical model.

Index Terms—technology transfer, technology gap, technology spillover, multinational corporations

I. Introduction

As effective way to transfer technology, foreign direct investment (FDI) has been widely paid attention to. Usually foreign direct investment is carried out on the premise of technology difference. In the process of technology transfer, technology gap is a key factor. To maintain market position, MNCs must rely on sustained technological advantages whereas the host country firms try to narrow the technological gap by independent innovation and technological spillover. Regardless of the different ways, the final goal of the host country firms is to narrow the technological gap and even exceed the MNCs.

Furthermore, until now many scholars have verified the spillover effect of FDI which is mainly derived from its positive externalities. And its contributions to the technology development of host-country firms are well recognized [1-8]. However, most studies in this field are empirical with the developed countries as the host country. Some studies on developing countries do not support for the view [9-17]. Apart from the discrepancy in methods, the fundamental reason for the difference of views is the difference in the absorptive capability of firms of different countries. Despite of lots of studies on the influence of learning efficiency of host-country firms on technology transfer [18-21], problems such as how the imitative capability and learning efficiency of host-country firms influence the technology transfer or under what circumstances the influence may happen still waits to be explored. What is more, the impact of market characteristics of host countries on technology transfer is also recognized important and interesting and needs to be further discussed [22-26]. And there are also some related studies. Nevertheless, most of these studies are empirical studies whose results are convincing but the underlying reasons for these results still need to be fully discussed.

Wang and Blomstrom (1992) developed a model in which international technology transfer through foreign direct investment emerges as an endogenous equilibrium phenomenon [27]. The model explicitly recognized two types of costs-the costs to the multinational of transferring technology to its subsidiaries and the learning costs of domestic firms. The analysis pointed to the importance of the learning efforts of host-country firms in increasing the rate at which MNCs transfer technology and explored some of the reasons why learning investment in host country firms may be suboptimal. By modifying Wang and Blomstrom's model [27], this paper discusses the issue of technology transfer. Based on mathematical deduction, this paper provides mathematical explanations for some results which remedies the defect of the empirical studies and enrich the current studies. And some of them are quite interesting comparing with other similar game models: (1) If the efficiency of learning activities of host-country firm is higher than the technology transfer efficiency of the MNC, the MNC is unwilling to transfer higher technology and the transfer speed is slow. (2) Product substitutability is positively related to technology transfer level and technology transfer speed while financing risks faced by the MNC are negatively related to technology transfer level and transfer speed. (3) The relationship between technology spillover and technology gap are uncertain. Keeping the optimal technology gap within certain range is most favorable for the rest-country firm.

II. Game Model

The aim of this paper is to explore the interaction and competition between MNCs and host-country firms in technology transfer. So the focus is placed on the cost and benefit analysis of the two sides. That is, a two-side game model is suitable for the analysis. Therefore, to simplify the problem, we suppose there are only one local firm and an affiliate of a MNC, producing differentiated products in host country. And the main difference between the local firm and the foreign affiliate is their accessibility to the advanced production technology. Supposing the R&D input of the foreign firm is x_f, the R&D cost is c_f. Correspondingly the

Manuscript received June 14, 2017; revised August 28, 2018. This work was supported by the China Scholarship Council, the National Natural Science Foundations of China (grant numbers: 71462009, 71361013), the Natural Science Foundations of Jiangxi Province (grant numbers: 20171BAA208013), and the Science and Technology Project of Jiangxi Provincial Department of Education (grant numbers: GJJ160435)

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learning input and learning cost of the host-country firm is respectively x_h, c_h. And the R&D cost is a strict convex function of R&D input. $k_i, i = f, h$ respectively denotes the technology level of the MNC and that of the host-country firm. Then k denotes the technology gap between the MNC and the host-country firm and it can be represented as

$$k(t) = k_f(t) - k_h(t) \tag{1}$$

We us $\pi_i(k)$ to denote the quasi-rent function of i firm. Then $\pi_i(k)$ can be stated as

$$\pi_i(k) = p_i(q_i)q_i - D_i(k_i) \qquad i = f, h \tag{2}$$

where $q_i, D(.)$ respectively denote the quantity and production cost of i firm. Considering the production of the product usually can be divided into two phases: the first phase is the creative intellectual phase in which only by large input the first product can be produced; The second phase is duplicate or repetitive production phase whose marginal cost is very small or even equal to zero. Therefore, we suppose production cost is the only function of technology level. The quasi-rent functions have the following attributes:

$$\pi_f' > 0, \pi_f'' < 0$$

$$\pi_h' < 0, \pi_h'' < 0$$

From them we can know that the quasi-rent function of the MNC is the increasing function of the technology gap. The more advanced the technology the MNC possesses, the more it can reduce unit production cost or increase market demand and hence increase quasi-rent. The quasi-rent function of the host-country firm $\pi_h(k)$ is a decreasing function of technology gap. The narrower the technology gap is, the more competitive the host-country firm is and hence the higher its quasi-rent is. Both quasi-rent functions are concave functions. The aim is to ensure the existence of solutions to both firms' maximization problem.

As we know, Technical knowledge is a kind of public product which has such characteristics as non-competitiveness and non-exclusiveness. The use of technical knowledge of one firm does not influence the use of the knowledge of other firms. And technical knowledge won't wear and tear due to use. On the contrary, it can be improved in use. Therefore, technical knowledge has a spillover effect.

According to above analysis, due to technology diffusion and the imitative activities of the host-country firm, the positive R&D externality can be captured by the local firm. Therefore, the effective learning input of the host-country firm is

$$E_h(t) = x_h(t) + \theta x_f(t), \qquad 0 \le \theta \le 1 \tag{3}$$

where θ denotes the technology imitative and absorptive capability of the local firm of the host country. Given that the learning input of the local firm of the host country is constant, the bigger θ is, the larger the positive externality the local firm captures is and the higher technology level is.

We use Dk_f to denote the rate of technology transfer and Dk_f is defined as:

$$Dk_f(t) = x_f(t) \tag{4}$$

where D denotes the time derivative of variable. To simplify it, we suppose the marginal productivity of R&D input x_f of the MNC is 1, which means we can use R&D input to denote technology level.

Findlay (1978) held the view that in a relatively backward country the rate of technology progress is the increasing function of technology gap [28]. We introduce the hypothesis in Findlay (1978) to the R&D process of the host-country firm to analyze the rate of technology progress of the host-country firm [28].

$$Dk_h(t) = \phi(E_h(t))\left[k_f(t) - k_h(t)\right] \tag{5}$$

where $\phi' > 0, \quad \phi'' < 0, \quad \phi(0) = v > 0$. ϕ denotes learning capability. It is the function of learning input. The constant v denotes the rate of costless technology spillover.

From equation (1), (4), (5), we can get technology transfer-absorption equation:

$$Dk = x_f - \phi(E_h)k \tag{6}$$

The MNC and the host-country firm simultaneously choose R&D input to maximize the discounted value of its profit stream v_i subject to the transfer-absorption process. Supposing discount rate is r.

We use v_i to denote the discounted value of profit of i firm and $i = f, h$. Then v_i can be expressed as:

$$v_i = \int_0^\infty e^{-rt}\left[\pi_i(k) - C_i(x_i)\right]dt \tag{7}$$

where $\mathrm{C_i}(.)$ denotes R&D or learning cost.

We first establish the Hamiltonian function of the MNC.

$$H_f(x_f, x_h, k, t) = \pi_f(k) - C_f(x_f) + \lambda_f\left[x_f - \phi(E_h)k\right] \tag{8}$$

In the above equation, λ_f can be explained as shadow value of marginal increase in input. The standard optimal control procedure yields the following first order necessary conditions:

$$\lambda_f = C_f'(x_f) \tag{9}$$

$$D\lambda_f = \left[r + \phi(E_h)\right]\lambda_f - \pi_f' \tag{10}$$

In the steady state we have $Dk = D\lambda_f = 0$. Given that the learning input of the host-country firm is constant, we can get the optimal shadow value λ_f^* and optimal technology gap k^* of R&D input.

$$\lambda^*_f = \frac{\pi'_f(k^*)}{r + \phi(E_h)} \qquad k^* = \frac{x_f}{\phi(E_h)} \tag{11}$$

Substituting (11) for (9) gives

$$T_f(x_f, x_h, r, \theta) = \frac{\pi_f'\left[x_f/\phi(E_h)\right]}{r + \phi(E_h)} - C_f'(x_f) = 0 \tag{12}$$

Similarly, we establish the Hamiltonian function of the host-country firm:

$$H_h(x_f, x_h, k, t) = \pi_h(k) - C_h(x_h) + \lambda_h\left[x_f - \phi(E_h)k\right] \tag{13}$$

Applying the same method we can get the optimal shadow value λ_h^* of R&D input of the host-country firm:

$$-\lambda^*_h = \frac{C_h'(E_h)\phi(E_h)}{\phi'(E_h)x_f} \tag{14}$$

Comparing with the shadow value of R&D input of the MNC we can know that λ_f^* is bigger than 0 while λ_h^* is smaller than 0. This is because given constant learning input of the host-country firm, increasing the R&D input of the MNC will enlarge the technology gap and therefore reduce profits of the host-country firm and increase monopoly profit of the MNC.

And we can know that maximizing the utility of the host-country firm should satisfy:

$$T_h\left(x_f, x_h, r, \theta\right) = \frac{-\pi_h'\left[x_f/\phi\left(E_h\right)\right]}{r+\phi\left(E_h\right)} - \frac{C_h'\left(E_h\right)\phi\left(E_h\right)}{\phi'\left(E_h\right)x_f} = 0 \quad (15)$$

From equation (12) and (15) we can get the steady-state x_f^*, x_h^*. And x_f^*, x_h^* is the Nash equilibrium of the dynamic game model.

III. TECHNOLOGY TRANSFER OF THE MNC AND THE BEHAVIORS OF THE HOST-COUNTRY FIRM

Proposition 1: for the MNC, the bigger the optimal technology gap is, the smaller the shadow value (marginal revenue) of R&D input of the MNC is and the more unwilling the MNC is to transfer higher technology to the host country.

Proof. From the attribute of quasi-rent function $\pi_f^{''} < 0$ we can know that $\pi_f^{'}(k^*)$ is a decreasing function. When the optimal technology gap is increasing, $\pi_f^{'}(k^*)$ is decreasing, which indicates the marginal revenue of R&D input of the MNC is decreasing. Therefore, given that the R&D input of the host-country firm and the interest rate of host country are constant, the bigger the technology gap is, the more unwilling the MNC is to transfer higher technology to host country.

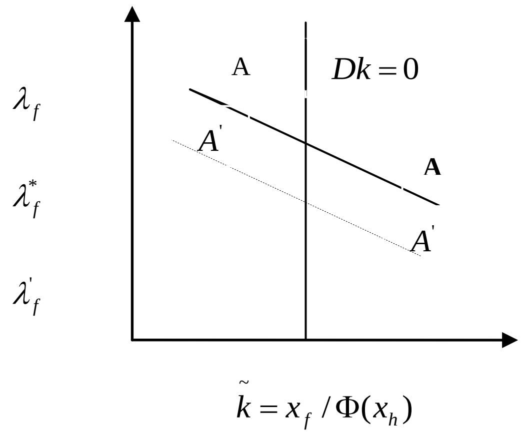

Fig. 1. The function curve of shadow value of R&D input on technology gap

From figure 1 we can clearly see that the function curve AA ($D\lambda_f = 0$) of shadow value of R&D input of technology gap is downward. Only when the technology gap between the MNC and the host-country firm is narrowing, the MNC has greater motives to transfer technology. The reason is that the bigger the technology gap is, the higher the competitive advantage of the MNC in host country market is and therefore the higher the monopoly profits are. Only transferring limited low-end technology can the MNC keep its leading position. Moreover, there exists the potential cost to transfer technology. All in all, on the one hand there is no necessity for the MNC to transfer technology and on the other hand the MNC is unwilling to invest more R&D capital to transfer technology if the technology gap is huge. Therefore, host country not only needs to formulate policies to encourage FDI but also needs to make greater efforts in increasing R&D investment, increasing technology spillover and reducing technology gap.

Proposition 2: for the MNC,

(1) when the discount rate is bigger, the financing risk of the MNC is increasing, which may result in the MNC's unwillingness to transfer technology or transfer very slowly.

(2) the stronger the imitation and absorption capability of the host country enterprise is, the higher the technology spillover degree is and the more unwilling the MNC is to transfer advanced technology to host country.

Proof. In equation (4)—the function of rate of technology transfer, we use x_f to denote faster technology transfer speed and higher technology level. From figure 1 we can see that given constant learning input of the host-country firm, when the discount rate is increasing or the imitative and absorptive capability of the host-country firm is increasing, curve AA will shift to $A'A'$. For $r' > r, \theta' > \theta$, we can get $\lambda_f' < \lambda_f^*$. We know $C_f^{''} > 0$. Therefore, from equation (9) we can get $x_f' < x_f^*$ which indicates the R&D capital input of the MNC for technology transfer is lower than the optimal level.

According to formula (6) we can get: the bigger the technology gap is, the slower the technology transfer speed is. Obviously we can get the optimum technology gap from Dk=0. That is, according to formula (11) we can know that the optimum technology gap depends on the endogenous variables of other economic factors, including learning input of the host country enterprises, R&D input of MNCs, technology spillover ect. This reminds us that when the developing countries are formulating their technology import policies, they cannot only consider the technology level of the programs. They should comprehensively consider the domestic technology level and the influence of the present system on technology import.

By referring to the response functions of the MNC and the host country enterprise, we can further analyze the Nash equilibrium of the game model. By combing formula (12) and formula (15), we can define the response function under equilibrium in the following ways:

$$x_f = \phi(x_h, \theta, r), \phi_f(0, \theta, r) = u, u > 0$$

$$\phi_f^{'} > 0, x_h = \phi(x_f, \theta, r), \phi_h^{'} > 0$$

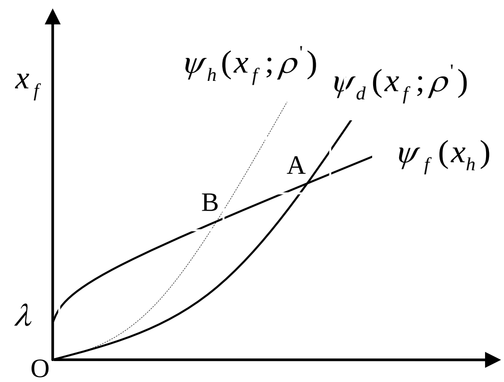

Fig. 2. The response functions of the host country firm and the MNC

The Nash equilibrium of the game model is decided by the intersection point of the two response functions. Given discount rate, the more the learning capital input of the host country enterprise is, the smaller the expected technology gap is. The reason is that when the host country enterprise increases the capital input of learning, the capability of applying advanced technology of local enterprise will increase which will make the local enterprise more competitive in domestic market and squeeze the monopoly profits of the MNC. To keep the monopoly status, the MNC usually will increase the capital input for technology transfer. We have supposed that $\phi(0)=v$, now we suppose $x_h=0, x_f=u$.

Proposition 3: under the following circumstances, the faster the technology transfer speed of the MNC is, the more probable it is for the MNC to transfer higher technology. (1) when the learning efficiency of the host country enterprise is relatively low; (2) when the substitution degree of competitive product is large. Generally speaking, technology transfer is positively related to capital input level of the host country enterprise for learning effect.

Proof. We transform equation (15) into:

$$\frac{\left|\pi_h'\right|}{r+\phi\left(E_h\right)}=\frac{C_h'\left(x_h\right)\phi\left(E_h\right)}{\phi'\left(E_h\right)x_f} \tag{16}$$

The left-hand side of the equation is the marginal revenue of learning input of the host-country firm in the steady state. The right-hand side of the equation is the marginal cost of learning input. We use $\left|\pi_i'\right|$ $(i=f,h)$ to denote product substitutability.

We suppose the learning function $\phi(.)$ of the host country enterprise adopts the form of exponent. We make $\phi_1=x_h^{\alpha}, \phi_2=x_h^{\beta}$. Obviously if $\frac{\phi_1'}{\phi_1}>\frac{\phi_2'}{\phi_2}$, we can get $\alpha>\beta$. Furthermore, when the R&D input of the host country enterprise is certain, we can get $\varphi_1>\varphi_2$. From the above analysis, we can know that to keep formula (16) to continue to exist, the higher the learning efficiency $\frac{\phi'}{\phi}$ of the host country enterprise is, the smaller the R&D input x_f of the MNC is, that is, it may result in that the MNC is unwilling to transfer higher technology and the technology transfer speed will be reduced. When the learning efficiency of the host country is relatively high, to some degree its technology imitation capability is relatively strong. To avoid the loss brought by technology spillover, MNCs are unwilling to transfer higher technology. When the learning efficiency of host country is relatively weak, the probability of technology spillover will also be small and there is more probable for the MNC to transfer higher technology.

When product substitutability is relatively high which indicates the competition in host country market is fierce, the marginal revenue of the host-country firm $\left|\pi_h'\right|$ is small. From equation (16) we can know that the R&D input of the MNC x_f is large. This is because the fiercer the competition in host country market is, the lower the expected profit of the MNC is. To keep its leading position in technology and maintain relatively high profit level, the MNC is willing to transfer higher technology.

Proposition 4: the higher technology spillover is, the faster technology transfer speed is.

Proof. Suppose $\phi(0)=v, \phi(0)'=v', v'>v$. According to formula (12), we have $x_f=\varphi_f(0\,|\,v)=u, x_f'=\varphi_f(0\,|\,v')=u'$. For $\varphi_f(.)$ is an increasing function, therefore $u'>u$. That is, when the degree of technology spillover increases, it will result in the increase of the technology transfer speed.

Proposition 5: if the efficiency of learning activities of host-country firm is higher than the technology transfer efficiency of the MNC, the MNC is unwilling to transfer higher technology and the transfer speed is slow.

Proof. From equation (12) we can get:

$$\frac{\pi_f'[{}^{x_f}\!/\!_{\phi(E_h)}]}{r+\phi(E_h)}=C_f'(x_f) \tag{17}$$

If the efficiency of learning activities of host-country firm is very big and even higher than the technology transfer efficiency of the MNC, it means the denominator of the left-hand side of the above equation is bigger while the numerator of the left-hand side is getting smaller. Therefore, the whole left-hand side of the equation is getting smaller. To satisfy the equation, the right-hand side of the equation must be reduced. And we know the cost function of R&D investment of the MNC is a convex function. Therefore, we can deduce that the MNC will reduce the R&D investment. That is, if the efficiency of learning activities of the host-country firm is higher than the technology transfer efficiency of the MNC, the MNC is unwilling to transfer higher technology and the transfer speed is slow. To some degree, this proposition is opposite to that of Wang and Blomstrom's model. According to Wang and Blomstrom, the more efficient the learning activities are, technologies will be transferred more rapidly and the more modern ones will be transferred [27]. Nakamura based on his model modified the proposition and he proposed that an increase in the efficiency of the host-country firm's learning activities accelerate technology transfer when the elasticity of the foreign firm's marginal quasi-rent with respect to technology gap is larger than unity in absolute value and vice versa [29]. The views of them have the implied assumption-the purpose of the MNC to transfer higher technologies and transfer technology more rapidly is to maintain the technology advantages so as to get the monopoly profits. We also accept this assumption. But differently we point out that the technology transfer and learning process is a dynamic process. On the one hand, if the learning efficiency of the host-country firm is high, the MNC will intend to transfer higher technologies and transfer them more rapidly to maintain the technology advantages. But on the other hand, if the learning efficiency of the host-country firm is higher than the technology transfer efficiency of the MNC, it means the more the MNC transfer the more the host-country firm will learn and comparatively the host-country firm will catch more advantages from the technology transfer. In fact, under such circumstances, the more the MNC transfers, the more advantages the MNC is losing. Therefore, the MNC will not have motives to transfer technology.

Proposition 6: the technology transfer of the MNC has threshold effect.

Proof. From equation (12) we can deduce that at any time it should be satisfied:

$$x_f > \frac{\pi_f^{'}\varphi^2}{-\pi_f^{''}(r+\varphi)} \quad (18)$$

From it we can know that the technology transfer of the MNC has the threshold effect. It indicates that the optimum technology transfer of the MNC must be higher than the threshold technology.

Proposition 7: the relationship between technology spillover and technology gap is unclear. Keeping the optimum technology gap within certain proper range is best beneficial for the host country enterprise.

Proof. From formula (15) when the utility of host country is maximized, at any time we have:

$$\phi^{'}(0) > \frac{C^{'}(0)(r+v)v}{\left|\pi_h^{'}(x_f/v)\right|x_f}$$

We use $\phi(0) = v$ to denote the technology spillover effect. At this time the R&D input of host country is 0. We can use the MNC's R&D input x_f to denote technology level gap. Because $\pi_h^{''} < 0$, $\pi_h^{'}$ is decreasing function. When technology gap is increasing, $\pi_h^{'}$ will reduce while v may increase or decrease. The relationship between technology gap and technology spillover is uncertain.

The influence of technology level gap on technology spillover has two sides: if the technology level gap between the MNC and the host country enterprise is too big, although there are many opportunities for the host country enterprise to learn the technology, the host country enterprise does not have enough technology capability to imitate and absorb the technology of the MNC which makes the final technology spillover effect is very small.

From the formula of optimum technology gap k^* we can see that when the learning input of host country is relatively large, the MNC should transfer higher technology to maintain sustainable R&D innovation, which shows that technology gap not only influence the technology level of direct investment but also influence the technology transfer speed of direct investment. Therefore, our country needs to take measures from many aspects such as concepts, systems, policies and attracting investment ways to accelerate the high-tech industry to take advantage of foreign investment.

IV. CASE ANALYSIS

Next through several practical cases, we further test the above propositions.

First we start our analysis with the development of the Chinese automobile industry. From the founding of New China to the 1990s, China's car industry has not basically accumulated its own technological capabilities. The technology gap between multinational corporations and Chinese automobile enterprises is still large, which has directly led to the low level and slow speed of technology transfer of multinational corporations. For example, except for the ordinary Santana model, Jetta introduced by FAW Volkswagen in 1990 was produced by its parent company 1982; in 1993, the Aoto model produced by the joint venture between Suzuki Japan and China Northern Industries, was developed by Suzuki in 1984. So it is mainly because that the technology level of Chinese car enterprises has not substantially improved in the past 15 years after the reform and opening up. When the automobile market opened up in the early 1990s and multinational companies entered on a large scale, the MNCs did not have the motive to transfer the advanced technology and products to China.

In contrast, the technology transfer of multinational companies in color TV is quite different from the situation of the car industry. Through the introduction of technology and transformation in the mid-1980s and 90s, China's color TV enterprises have accumulated considerable technological capabilities and the technology gap between Chinese and foreign enterprises has been greatly narrowed. This propelled multinational companies to improve the level and the speed of technology transfer. From 1978 to 1985, a total of 113 color TV assembly lines were introduced into China, covering 25 provinces, autonomous regions and cities. These technologies mainly originated from Hitachi, Matsushita Philips, Sony and other famous companies. Since then, the Chinese enterprises began to tackle the crucial problems in color TV industry. By the early 1990s, the domestic color TV producers had already possessed considerable technical capacity and the annual output growth rate of the main types of color TV set reached more than 30%. From the beginning of the 1980s to the end of the price war in the 1990s, China's color TV enterprises have accumulated considerable technical capacity. Therefore, after 1998, when foreign color TV enterprises began to enter China, they had to adopt the strategy of transferring high-end technology and accelerating the production of high-end products. So for the above two cases, proposition 1 is verified.

IT industry has the characteristics with large initial investment, short life cycle and high risks. The IT enterprises in the host country usually have to pay a large initial fixed cost (including learning cost, negotiation cost, purchase cost of key technology and equipment, etc.) for the use of advanced technology of multinational companies. The operation of the host country's domestic financial market largely determines whether the enterprises can get the loan to pay these fixed costs. In China, a developing country, the interest rate of venture capital is bigger than that of developed countries such as the United States, Britain and Europe. Besides, there are fewer financing channels. So it is relatively difficult for IT entrepreneurs to finance in China. The financial environment is closely related with the development capability of enterprises and therefore can influence technology transfer. One of the results of the unfavorable financial environment in China is that in the early cooperation with IT enterprises in China multinational corporations tended to transfer less technology to them. So the first part of proposition 2 is verified.

When the substitution degree of products is relatively big and the competition of market in the host country is fierce, the expected profits of the MNCs in the host country are low. To maintain its lead position in technology and the profit level, generally the MNCs are willing to provide higher technology. This is what is happening in China's car industry. In China, the competition of the car market is fierce. The cars with various brands and various producers are competing with each other. In such host country, to maintain the profit level, the MNCs investing in the local enterprises are changing the former strategy and are gradually transferring more and higher technology to its subsidiaries so as to keep the competitiveness. With this case, the second part of proposition 3 is verified.

However, the relationship between learning efficiency, absorptive capability and technology transfer is another side of the problem. Although higher technology transfer level can provide big monopoly profits for the MNCs, due to the technology diffusion or technology spillover, the more technology the MNCs transferred, the greater loss the MNCs may have if the local enterprises have high learning efficiency and absorptive capability. That is why in the process of development of many emerging countries such as the former Korea, Japan or today's China, the MNCs always take the conservative technology transfer strategy. So for this fact, the second part of proposition 2, the first part of proposition 3 and the proposition 5 are verified.

Theoretically, there are three ways of positive technology spillover: imitation-demonstration effect, vertical linkages and labor transfer. We take vertical linkages as an example. Vertical linkages are seen as an inter-industry spillover, including post-spillover (the spillover on local suppliers) and forward-spillover (the spillover on the local customers). In China, the vertical linkages are mainly embodied as the MNCs use product match strategy to make technology spillover on the local producers. In recent years, multinational companies are increasingly focusing on localization of parts and components. In this way, the technology spillovers of multinational corporations increase. At the same time, we find that with the localization of multinational corporations, the technical capability of local parts production enterprises has been greatly improved. Thus with higher technology spillover, the capability of local enterprises are improved and therefore the technology is transferred more. As such, proposition 4 is verified.

For Proposition 6, this paper mainly demonstrates a self-evident, objective phenomenon in FDI by mathematical deduction. Therefore, we have not further verified it. For proposition 7, we find a rough relationship between technology spillovers and technological gap through the mathematical deduction. But the relationship is not clear enough. We hope by future research, we can propose some more specific conditions to further clarify the relationship between the two elements. In this paper we have not provided relevant case proof to verify this proposition.

V . CONCLUSIONS

Based on the game analysis, this paper deduces some propositions. The proposition that if the efficiency of learning activities of the host-country firm is higher than the technology transfer efficiency of the MNC, the MNC is unwilling to transfer higher technology and the transfer speed is slow complements the understandings of Wang and Blomstrom's model as well as Nakamura's model. Comparing with Wang and Blomstrom's model, it points out that it is the comparative learning efficiency of the host-country firm that influences technology transfer rather than the absolute learning efficiency. Furthermore, for Nakamura he proposed that an elasticity of the foreign firm's marginal quasi-rent plays a key role in determining the effects of learning efficiency on technology transfer. The underlying assumption is that the technology transfer of the MNC can definitely enlarge the technology gap. Differently, this paper puts forward another possibility-when the learning efficiency of the host-country firm is greater than the technology transfer efficiency of the MNC, it indicates the technology transfer of the MNC may not enlarge the technology gap and therefore the MNC may not have the motive to transfer technology. So it also complements Nakamura's model. Apart from this finding, some other interesting results such as the positive relationship between product substitutability and technology transfer, the negative relationship between financing risks and technology transfer, and the uncertain relationship between technology gap and technology spillover, and the threshold effect of technology transfer of the MNC ect are also enlightening for understanding technology transfer. However, this paper mainly discusses the industries which need relatively high technology. The technology transfer in other industries needs to be further discussed. Besides, this paper proposes 7 propositions and it provides several practical cases to verify five of them. More empirical studies to test these propositions are regarded important and worthwhile.

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