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The effect of strategic technology adoptions by local firms on technology spillover☆

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ABSTRACT

This paper examines the influence on technology spillover of the strategic decisions by local firms to adopt the advanced technology of multinationals, which has in fact been ignored in previous studies. To do so, we construct a theoretical model by combining technology adoption and technology spillover models through backward linkage. If the technological gap is large between the multinational and local firm, it may be reasoned that the local firm is making the strategic decision not to adopt the advanced technology in order to avoid direct competition with the multinational firm. In this case, even though the transferred technology is diffused and the local firm has the capacity to absorb it, the technology spillover may not occur. Additionally, we apply the model to analyze the effect of local content requirements (LCR) on technology transfer and technology spillover. The analysis shows that LCR may fail to enhance technology spillover because these do not encourage the adoption of the technology.

1. Introduction

Over the last several decades, one of the most controversial issues in international economics regarding foreign direct investment (FDI) has been the technology spillover from multinationals to local firms. The controversy continues mainly because empirical studies have apparently failed to find consistent evidence of positive technology spillover, even through FDI, if it occurs, is considered one of most important methods for local firms to increase their productivity in host countries.[2] In particular, whereas many studies reported on the positive technology spillover,[3] an equal number have reported either no evidence of technology spillover or actual negative spillover.[4] Failure of previous empirical work to find positive technology spillover might be due to the econometric measurement problems as Xu (2000) suggests.[5] However, as Görg and Greenaway (2004) argue, it is more likely because there are many factors that determine technology spillover in reality.[6]

Among the many technology spillover determining factors, the heterogeneous absorptive capacity[7] and the technological gap of local firms might be the most widely studied factors that generate inconsistent technology spillover across countries and industries (Lapan and Bardhan, 1973; Findlay, 1978; Wang and Blomström, 1992; Kokko, 1994; Kokko et al., 1996; Perez, 1997; Borensztein et al., 1998; Xu, 2000; Kinoshita, 2001). The intuitive reasoning behind the significance of absorptive capacity is simple: since technology absorption requires firms to have the capacity to absorb it, only capable local firms can internalize such technology from multinationals. Hence, technology spillover is more likely to occur if the local firm has a greater capacity to absorb the advanced technology. The technological gap between multinationals

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2 Smeets (2008) also argues that "recent surveys of the empirical literature have concluded that the evidence is mixed on the magnitude, direction, and existence of the knowledge spillovers from FDI."

3 Examples of selected studies that find a positive spillover are Caves (1974), Globerman (1979), Blomström and Persson (1983), Barrell and Pain (1997), Borensztein et al. (1998), Hejazi and Safarian (1999), Cheung and Lin (2004), Liu (2008), and Javorcik and Spatareanu (2008).

4 Examples of selected studies that find a negative spillover are Haddad and Harrison (1993), Lichtenberg and de la Potterie (1998), Aitken and Harrison (1999), Djankov and Hoekman (2000) and Sonn and Lee (2012).

5 Although most empirical studies use productivity as a proxy in measuring technology spillover, it is a poor proxy for spillover itself. Hence, results regarding the spillover that occurs from FDI may differ across studies (Xu, 2000).

6 Görg and Greenaway (2004) and Crespo and Fontoura (2006) classify five determinant factors of technology spillover: abortive capacity and technology gap of host countries and local firms, geographical dimensions, characteristics of local firms, characteristics of FDI, and others. Further, they provide useful surveys for research regarding technology spillover by FDI or multinationals.

7 Görg and Greenaway (2004) define the absorptive capacity as local firms' relative backwardness and their capacity for assimilating knowledge.

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and local firms has two opposite effects on spillover. As several researchers argue (Findlay, 1978; Wang and Blomström, 1992), a larger technological gap can encourage local firms to absorb the better technology from the multinational, as it would be motivated to catch-up technologically. On the other hand, the larger technological gap may also require that local firms have a greater absorptive capacity, and thereby deter technology spillover. Therefore, technology spillover is more likely to occur if the technological gap between multinationals and local firms is not too great (Lapan and Bardhan, 1973; Wang and Blomström, 1992; Kokko, 1994; Kokko et al., 1996; Perez, 1997; Borensztein et al., 1998; Kathuria, 2000; Görg and Strobl, 2000, 2003; Kinoshita, 2001). This theory can be applied in macro-level analysis. On the basis of the assumption that the technological/economic development of the host country and the number of skilled workers determine local firm absorptive capacity and the technological gap, some studies report that those factors can be determinants of technology spillover in host countries (Blomström et al., 1994; Borensztein et al., 1998; Xu, 2000; Ahmed, 2012). Further, they report that less-developed countries and sectors that employ a relative number of unskilled workers are less likely to see positive technology spillover.

Thus, the influence of absorptive capacity and technological gap on technology spillover provides a reasonable explanation for the mixed evidence on technology spillover from multinationals. However, it seems that our understanding regarding the role of absorptive capacities and technological gap on technology spillover is still incomplete in terms of the mechanisms transmitting advanced technology from multinationals to local firms. In particular, most previous studies ignore the strategic decisions of the local firms that are receiving the diffused technology. That is, those studies assume that transferred technology will be diffused to local firms and automatically adopted by them. However, as widely discussed in the literature on industry organization, technology adoption is a strategic choice made by a firm, and it is possible that diffused technology is dismissed by local firms in a competitive market environment. Clearly, if the diffused technology is not adopted by local firms, the technology spillover will not be observed. Furthermore, the lack of strategic adoption of diffused technology by local firms implies that the technology spillover could not occur even if local firms have the capability to absorb the advanced technology. Surprisingly, no studies have incorporated the strategic decision-making of the local firms in the process of the transfer, diffusion, and adoption of technology.

This study examines the role of technology transfer by multinationals and its strategic adoption by local firms in terms of technology spillover. To do so, we employ the model of vertical product differentiation,[8] as in Mussa and Rosen (1978), to incorporate strategic technology adoption into the process of technology transmission from a multinational to a local firm.[9] While considering the strategic choice of technology transfer by multinationals and technology adoption by local firms, we construct a simple theoretical model to analyze the technology spillover. Particularly, we consider technology transfer and diffusion in vertical production, as in Pack and Saggi (2001).[10] The new technology of a multinational in a developed country (DC) can be transferred to selected local input suppliers in the host country, whereupon it diffuses to non-selected local input suppliers. If necessary, a local final-good producer that is a competitor to the multinational in the host country may adopt the diffused technology.[11] The two final-good producers—namely, the multinational and the local producer—compete with each other in the market in terms of price and quality. Using the constructed model, we show that if the technological gap between the multinational and the local firm is large, the local producer may not adopt the diffused technology to avoid competition with the multinational producing high-quality products in this market. In such cases, the technology spillover is not observed, even though the transferred technology has been diffused to the local firm and the local firm has the ability to adopt it. Furthermore, given the technological gap, when local firms have a greater absorptive capacity for the diffused technology, the probability of technology spillover increases. In addition, we apply the model to analyze the effect of a policy to enhance technology transfer and technology spillover that encourages the local production of intermediate inputs to production, rather than imports from the multinational's home country. Such a policy is often termed local content requirements (LCR). The analytical results show that using LCR to enhance technology spillover may fail as these do not encourage technology adoption by local firms. Under LCR, the local firm may not adopt the diffused technology as it wants to avoid competition with the multinational that produces high-quality products in the local market.

The rest of the paper is organized as follows. Section 2 presents a simple model to analyze technology spillover. Section 5 discusses the strategic choices of the two final-good producers and the equilibrium of sequential games. In Section 6, we apply the developed theoretic model to analyze LCR policy. Section 7 summarizes the results, and concludes the paper.

2. Model

Suppose there are two final-good producers, a multinational U from a developed country (DC) and a local firm K in a developing country (LDC), which compete against each other in terms of the quality and price of the final good in LDC. The two producers are assumed to produce a final good using a unit mass of intermediate inputs. All intermediate inputs are assumed to differ in terms of their characteristics. That is, the two firms are assumed to combine infinitely many differentiated intermediate inputs to produce final goods. Further, suppose that any differentiated intermediate input can have varying quality depending on the level of technology that the input supplier possesses; also, the quality of an intermediate input is measured as $\lambda \in [0, 1]$. The quality of the final good depends on the quality of the intermediate inputs that the producer purchases. In other words, the two final-good producers can choose the quality of their own product by choosing the quality of the procured intermediate inputs.

2.1. Intermediate inputs and qualities

Regarding input supplies, a differentiated intermediate input can be produced by upstream firms in either LDC or DC, but the input suppliers in DC are assume to possess new technology. Particularly, assume that an upstream firm in LDC, say 'old supplier,' is equipped initially with old technology, and can produce a low-quality input, say 'old inputs,' using one unit of labor input at the wage of LDC (w_{LDC}). Further, the quality of an old input is assumed to be λ^{old}. Assuming there are many upstream firms in LDC that all compete on price, the price of an old input in LDC is the marginal cost of the local old-input suppliers, that is,

[8] Consumers will buy high-quality goods, when high- and low-quality goods are offered at the same prices. They will buy lower-quality goods only if they are offered at sufficiently lower prices.

[9] According to Markusen (1995), "multinationals tend to be important in industries and firms with four characteristics: …products that are new and/or technically complex; and high levels of product differentiation and advertising." Further, recent analysis reveals a substantial number of traded products with various relative qualities. For example, Schott (2004) finds that across all U.S. manufacturing imports in 1994, the median ratio of high to low unit values was 24. This price variation suggests the importance of vertical differentiation, with higher prices reflecting in part higher product quality (Bernard et al., 2007).

[10] Görg and Greenaway (2004) and Crespo and Fontoura (2006) classify five spillover channels: demonstration by multinationals and imitation by local firms, labor mobility from multinationals to local firms, export, competition, and backward or forward linkage between multinationals and local firms. Based on their classification of the spillover channels, we consider the spillover channel through backward linkage. Further, Blomström and Kokko (2003) stated "… case studies showed that foreign MNEs may … transfer techniques for inventory and quality control and standardization to their local suppliers and distribution channels."

[11] Kwon and Chun (2009) construct a similar framework to analyze the effect of local-content requirements on technology transfer and diffusion by multinationals. However, they do not consider strategic technology adoption by local firms.

w_{LDC}. Assume that any input supplier in DC possesses a new technology, and can produce intermediate inputs that have a high quality of $\lambda^{new} > \lambda^{old}$ (call such a high-quality input 'new input') using one unit of labor input at the wage of DC (w_{DC}). The input suppliers in DC can supply the new inputs to the multinational, U, in LDC with a transportation cost of τ_u. For later use, define the technological gap between the new and old suppliers as $\Delta\lambda^{no} \equiv \lambda^{new} - \lambda^{old} > 0$. To focus the analysis on technology transfer rather than the intrinsic production cost, assume the wage in DC is the same as that in LDC: $w_{DC} = w_{LDC} \equiv w$.

As with input suppliers in DC, the multinational U from DC also possesses new technology, and if it desires, can transfer the new technology to selected local suppliers in LDC. Then, the selected local suppliers become 'local new suppliers' and can produce a new input that has a high quality of λ^{new} using one unit of labor.[12] Although the multinational U can enjoy high-quality input, technology transfer may require the multinational U and the local new suppliers to pay an additional cost to train local unskilled workers in the downstream sector. Then, the marginal costs of a local new supplier and the multinational U are $w_{LDC} + \theta$ and $w_{LDC} + \theta + \psi$, respectively,[13] where $\theta \geq 0$ and $\psi \geq 0$ are the additional costs of training one unit of local unskilled workers that is incurred by the local new supplier and multinational U, respectively.[14] Moreover, the transferred technology can be diffused to non-selected local old suppliers. Particularly, due to technology diffusion, non-selected local old suppliers can produce a 'quasi-new input' that has a quality of $\lambda^{qnew} \in [\lambda^{old}, \lambda^{new}]$. Hence, the local final-good producer K can produce either better product by purchasing quasi-new inputs from local old suppliers or low-quality product by purchasing old inputs, but the improved quality of inputs still may be lower than that of the new inputs. For later use, define the technology difference between the quasi-new and old suppliers as $\Delta\lambda^{qno} \equiv \lambda^{qnew} - \lambda^{old} \geq 0$. Also, define the technological gap between the new and quasi-new suppliers as $\Delta\lambda^{nqn} \equiv \lambda^{new} - \lambda^{qnew} \geq 0$. The price of a quasi-new input is simply w_{LDC} since quasi-new input suppliers compete on the basis of price.

3. Quality choice: technology transfer and technology adoption

First of all, consider the case that multinational U purchases intermediate inputs from local suppliers in LDC. Then, the quality of the final goods that multinational U produces depends on the magnitude of technology transfer by the multinational to local suppliers. Let ϕ represent the magnitude of technology transfer by multinational U, and define $\phi \in [0, 1]$ as the portion of intermediate inputs produced through technology transfer of all the intermediate inputs produced in LDC. Then, multinational U produces one unit of the final good using an amount ϕ of new inputs and an amount $1 - \phi$ of old inputs; further, the quality of the final goods produced by multinational U can be expressed as follows.

$$\lambda_U(\phi) = \phi\lambda^{new} + (1-\phi)\lambda^{old} \tag{1}$$

When multinational U transfers the technologies to the selected local input suppliers, the transferred technologies are diffused to non-selected local input suppliers, and local final-good producer K can produce better products by purchasing quasi-new inputs, if desired. Let ρ represent the technology adoption rate of firm K, and define $\rho \in [0, 1]$ as the fraction of quasi-new inputs that are purchased by local firm K of all the available quasi-new inputs through technology diffusion. Then, firm K produces one unit of better final goods by using an amount $\rho\phi$ of quasi-new inputs and an amount $1 - \rho\phi$ of old inputs. Further, the quality of final goods produced by local firm K can be expressed as follows.

$$\lambda_K(\phi, \rho) = \rho\phi\lambda^{qnew} + (1-\rho\phi)\lambda^{old}. \tag{2}$$

Clearly, firm U produces a better final good than does the local firm, i.e., $\lambda_U \geq \lambda_K$ because $\phi \in [0, 1]$, $\rho \in [0, 1]$, and $\lambda^{qnew} \in [\lambda^{old}, \lambda^{new}]$. Note that the quality of firm K's product is simply $\lambda_K = \lambda^{old}$ without technology adoption.

4. Sequence of the game, marginal cost of production, and demand structure

Given the technology, assume that the two final-good producers, multinational U and local firm K, play the following three-stage game:

1. Multinational U decides whether it purchases the intermediate input from DC suppliers or LDC suppliers.
2. If multinational U purchases the intermediate inputs from LDC suppliers, the firm decides whether it transfers the superior technology to the selected local suppliers. If firm U decides to do so, it can produce the final good with high quality, but technology diffusion can occur to the non-selected local suppliers. Also, multinational U chooses an amount ϕ for technology transfer.
3. Once technology diffusion occurs, the non-selected local suppliers can produce the quasi-new inputs, and the local final-good producer K can decide whether or not it purchases the quasi-new inputs. If firm K purchases the quasi-new inputs, it can produce a better final good than before. Otherwise, firm K continuously produces low-quality products. Further, firm K chooses an amount ρ for the adoption of the diffused technology.
4. Given the qualities of the two firm's final goods, the two firms compete against each other in Bertrand fashion.

Note that, assuming that assembly of intermediate inputs to produce final goods does not entail any cost, the marginal cost of production for multinational U by importing DC intermediate inputs is simply $mc_U^{DC} = w_{DC} + \tau$. However, the marginal cost for multinational U by purchasing LDC inputs depends on ϕ and the training cost to transfer the technology. Thus, if multinational U decides to purchase LDC inputs, the marginal costs of production for the two final-good producers are:

$$\begin{aligned} mc_U^{LDC}(\phi) &= \phi(w_{LDC} + \theta + \psi) + (1-\phi)w_{LDC} = w_{LDC} + \phi(\theta + \psi) \\ mc_K &= w_{LDC}, \end{aligned} \tag{3}$$

where mc_i denotes the marginal cost of firm i.

Turning to the preferences of consumers, consider a standard preference for vertically differentiated products. Consumers differ from one another with respect to their preference/taste for the quality of the final good; the taste parameter, η, is uniformly distributed over the interval, [0, 1]. Assume that each consumer purchases only one unit of the final good. When consumers purchase a product with quality λ^c at price p, the surplus that the type η consumer earns is $U = \eta\lambda^c - p$. The consumer is indifferent between qualities λ_U and λ_K when she has the following taste:

$$\hat{\eta}^c = \frac{p_U - p_K}{\lambda_U - \lambda_K}. \tag{4}$$

Therefore, the demands for the products produced by multinational U and firm K are $D_U = 1 - \hat{\eta}^c$ and $D_K = \hat{\eta}^c$, respectively. From the demands for the two firms, we can derive the prices of products and the profits of the two firms in a price game:

$$p_U = \frac{1}{3}[2mc_U + mc_K + 2(\lambda_U - \lambda_K)]; \; p_K = \frac{1}{3}[mc_U + 2mc_K + (\lambda_U - \lambda_K)] \tag{5}$$

[12] Firm K may learn how to use the new technology through technology transfer. However, in this paper, we assume that multinational U does not transfer its know-how in production directly to its competitor (local firm K).

[13] Note that the input suppliers will accept any offers of technology transfer to guarantee non-negative profits, because their profits with the old technology are zero. Thus, multinational U can extract all the rent that originates from the technology transfer.

[14] Similar to the arguments of Glass and Saggi (2002), the training costs, θ and ψ, can be thought of as wage premiums to prevent old input suppliers from hiring the new input suppliers' workers and thus gaining full access to advanced technology.

$$\pi_U(\phi,\rho) = \frac{[mc_K - mc_U(\phi) + 2(\lambda_U(\phi) - \lambda_K(\phi,\rho))]^2}{9(\lambda_U(\phi) - \lambda_K(\phi,\rho))} \tag{6}$$

$$\pi_K(\phi,\rho) = \frac{[mc_U(\phi) - mc_K + (\lambda_U(\phi) - \lambda_K(\phi,\rho))]^2}{9(\lambda_U(\phi) - \lambda_K(\phi,\rho))}. \tag{7}$$

5. Strategic choices of firms: technology diffusion without the technology spillover

First, it should be noted that the local firm K's profit function (Eq. (7)) is convex with respect to ρ,[15] and that its optimal choice is either $\rho = 0$ or $\rho = 1$. Additionally, multinational U's optimal choice is simply $\phi = 1$ because its profit function (Eq. (6)) is strictly increasing with respect to ϕ.[16] Thus, when multinational U decides to purchase local intermediate inputs, it transfers new technology to the selected local suppliers; this is because multinational U prefers to occupy the high-quality product market and avoid competing with the local final-good producer in the low-quality product market. For simplicity, we assume that wages in DC and LDC are identical:

Assumption 1. $w_{DC} = w_{LDC} = w$.

Fig. 1 and Table 1 show the game tree and the pay-off matrix of the game, respectively. It should be noted that (import, $\rho = 0$) and (import, $\rho = 1$) are identical because multinational U does not transfer adoptable technology.

First, we consider the strategic choice of local firm K at the second stage when multinational U chose local outsourcing at the first stage. By comparing the profits shown in Table 1, we can obtain the following decision rule for K:

$$\pi_K(\rho = 1; \text{out}) \geq \pi_K(\rho = 0; \text{out}) \text{ if } \Delta\lambda^{no} \leq \frac{1}{2}\left[\Delta\lambda^{qno} + \sqrt{(\Delta\lambda^{qno})^2 + (\theta+\psi)^2}\right] \equiv \bar{\lambda} \tag{8}$$

Decision rule (8) indicates that diffused technology will only be adopted if $\Delta\lambda^{no} \leq \bar{\lambda}$. Thus, the adoption decision of local firm K depends on $\Delta\lambda^{no}$ and $\bar{\lambda}$, which are determined exogenously by the technological gap and other parameters.

Now, we consider the case where $\Delta\lambda^{no} \leq \bar{\lambda}$ and local firm K adopts the diffused technology if it is transferred by multinational U. By comparing the profits shown in Table 1, we can see that multinational U's decision rule at the first stage is:

$$\pi_U(\text{out}, \rho = 1) \geq \pi_U(\text{import}) \text{if} \tau \geq \bar{\tau} \tag{9}$$

where $\bar{\tau} \equiv 2(\Delta\lambda^{no} - \sqrt{\Delta\lambda^{no}\Delta\lambda^{nqn}} + (\theta+\psi)\sqrt{\Delta\lambda^{no}/\Delta\lambda^{nqn}})$. Decision rule (9) shows that, if $\tau \geq \bar{\tau}$, multinational U will purchase domestically-produced inputs with technology transfer even though the technology will be diffused to the local rival; otherwise, it will import home-produced inputs.

When $\Delta\lambda^{no} \geq \bar{\lambda}$, local firm K will not adopt the diffused technology even if multinational U transfers it to local suppliers. Consequently, multinational U faces the following decision rule:

$$\pi_U(\text{out}, \rho = 0) \geq \pi_U(\text{import}) \text{if} \tau \geq \theta + \psi. \tag{10}$$

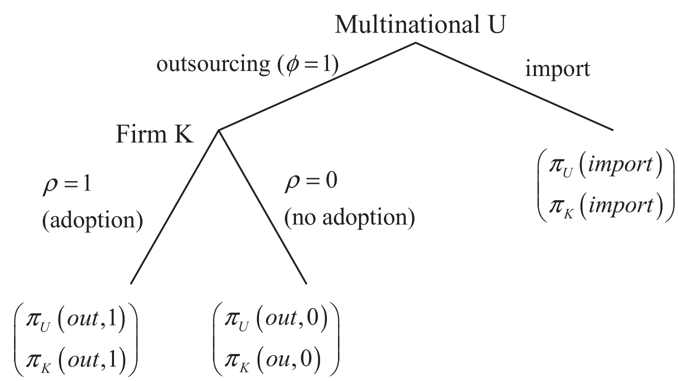

Fig. 1. The profit matrix.

Decision rule (10) indicates that if $\tau \geq \theta + \psi$ multinational U will choose to outsource locally with technology transfer rather than to import home-produced inputs. However, there will be no observable technology spillover because local firm K will discard the diffused technology.

Since $\theta + \psi < \bar{\tau}$, we may obtain the following proposition from decision rules (8), (9), and (10).[17]

Proposition 1. *Given the assumptions, the structure of the game, and the entry of multinational U into LDC,*

(1) *if $\Delta\lambda^{no} \leq \bar{\lambda}$ and $\tau \leq \bar{\tau}$, U will import home-produced inputs,*
(2) *if $\Delta\lambda^{no} \leq \bar{\lambda}$ and $\tau \geq \bar{\tau}$, U will transfer the technology and local firm K will adopt the diffused technology.*
(3) *if $\Delta\lambda^{no} \geq \bar{\lambda}$ and $\tau \leq \theta + \psi$, U will import home-produced inputs, and*
(4) *if $\Delta\lambda^{no} \geq \bar{\lambda}$ and $\tau \geq \theta + \psi$, U transfers the technology and local firm K does not adopt the diffused technology.*

Note that a technology spillover can only be observed if local firm K adopts the diffused technology, and thus, the necessary condition to observe such a technology spillover is $\Delta\lambda^{no} \leq \bar{\lambda}$. Hence, we obtain the following corollary from Proposition 1.

Corollary 1.1. *Given the assumptions, the structure of the game, and the entry of multinational U into LDC, a technology spillover from the transferred technology if $\Delta\lambda^{no} \leq \bar{\lambda}$. Otherwise, a technology spillover will not be observed.*

Local firm K will adopt the diffused technology if the diffused quasi-new technology enables local firm K to compete with multinational U. Otherwise, it will not adopt the diffused technology, and will subsequently produce a low-quality product to capture a large market-share at a low price. The decision rule $\Delta\lambda^{no} \geq \bar{\lambda}$ implies that if the technological gap between the firms in the DC and LDC were large, then the local firm K would not adopt the diffused technology, because the large technological gap between local firm K and multinational U can provide sufficiently clear product differentiation.[18] In fact, the local firm would prefer to capture a large market-share at a low price by producing the current, low-quality products. If the technological gap were small and the full quality-differentiation does not provide a sufficiently large market-share to local firm K, however, the local firm would adopt the diffused quasi-new technology and compete with multinational U by producing a better product at a high price. Consequently, Proposition 1 and Corollary 1.1

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[15] The second derivative of the profit function of firm K is $\frac{2\cdot\phi\cdot\Delta\lambda^{qno}\cdot(\theta+\psi)^2}{9\cdot(\Delta\lambda^{no}-\rho\cdot\Delta\lambda^{qno})^3} \geq 0$ where $\Delta\lambda^{no} = \lambda^{new} - \lambda^{old} > 0$ and $\Delta\lambda^{qno} = \lambda^{qnew} - \lambda^{old} \geq 0$.

[16] The U's profit can be expressed as:

$$\pi_U(\phi,\rho) = \frac{\phi(2(\Delta\lambda^{no} - \rho\Delta\lambda^{qno}) - (\theta+\psi))^2}{9(\Delta\lambda^{no} - \rho\Delta\lambda^{qno})}.$$

Thus, $\pi_U(\phi,\rho)$ is clearly strictly increasing in ϕ.

[17] $\theta + \psi < \bar{\tau}$ because $\Delta\lambda^{no} - \sqrt{\Delta\lambda^{no}\Delta\lambda^{nqn}} \geq 0$ and $\Delta\lambda^{no}/\Delta\lambda^{nqn} \geq 1$.

[18] Belderbos et al. (2008) studies the R&D allocation of multinationals using the similar setting. They find that the technological gap between two multinationals affects on the firms' quality choice: if technological gap with the laggard is large, the lagging multinational may have incentive to produce lower quality produce to avoid competition. The result of Belderbos et al. (2008) is similar to ours, but they consider the quality competition between multinationals and does not consider the adoption of the diffused technology by local firms.

Table 1
The profit matrix of the game.

π_U; π_K		Firm K (follower)	
		$\rho = 0$ (no adoption)	$\rho = 1$ (adoption)
Firm U (first mover)	Local outsourcing and $\phi = 1$ (out)	$\frac{[2\Delta\lambda^{no} - (\theta+\psi)]^2}{9\Delta\lambda^{no}}; \frac{[\Delta\lambda^{no}+\theta+\psi]^2}{9\Delta\lambda^{no}}$	$\frac{[2\Delta\lambda^{nqn} - (\theta+\psi)]^2}{9\Delta\lambda^{nqn}}; \frac{[\Delta\lambda^{nqn}+\theta+\psi]^2}{9\Delta\lambda^{nqn}}$
	Import from home (import)	$\frac{[2\Delta\lambda^{no} - \tau]^2}{9\Delta\lambda^{no}}; \frac{[\Delta\lambda^{no}+\theta+\psi]^2}{9\Delta\lambda^{no}}$	$\frac{[2\Delta\lambda^{no} - \tau]^2}{9\Delta\lambda^{no}}; \frac{[\Delta\lambda^{no}+\theta+\psi]^2}{9\Delta\lambda^{no}}$

imply that if the technological gap between the DC and the LDC were large, technology diffusion may occur, but the technology spillover would not.[19]

Finally, it should be noted that, by definition of $\Delta\lambda^{qno}$, $\partial\overline{\lambda}/\partial\lambda^{qnew} \geq 0$. Hence, decision rule (8) implies that local firm K has a greater chance of adopting the diffused technology as λ^{qnew} is grows closer to λ^{new}. That is, if the diffused quasi-new technology is good enough for local firm K to allow local firm K to compete with multinational U, local firm K will adopt it and produce better products at higher prices. However, if the diffused technology is insufficient for local firm K to allow it to compete with the multinational, local firm K will not adopt the diffused technology, and instead prefer to capture a large market-share by producing its current, low-quality products. Alternatively, since the higher $\Delta\lambda^{qno}$ implies that the local firm has a better ability to absorb the diffused technology, $\Delta\lambda^{qno}$ might be interpreted as the absorptive capacity of the local firm. Under this alternative interpretation, $\partial\overline{\lambda}/\partial\lambda^{qnew} \geq 0$ and decision rule (8) suggest that a local firm with a higher absorptive capacity is more likely to adopt the diffused technology and exhibit technology spillover. This coincides with the arguments of previous studies regarding absorptive capacity and technology spillover (Lapan and Bardhan, 1973; Wang and Blomström, 1992; Kokko, 1994; Kokko et al., 1996; Perez, 1997; Borensztein et al., 1998; Kinoshita, 2001).

6. Application: local content requirements without a technology spillover

The previous section clarifies that technology transfer without technology spillovers may transpire due to the strategic choices of firms. The result implies that in some circumstances, any effort of government to enforce domestic production and technology transfer on the part of multinationals, in the expectation of technology spillovers, can fail.[20] In this section, we apply our theoretical model to analyze the local content requirement (LCR) that is a government policy that requires multinationals to use a certain fraction of locally produced intermediate inputs.[21]

Consider the same situation as in the previous section. There are two final-good producers, multinational U and local firm K, which are competing against each other on price and quality. Further, assume that the assumptions regarding technology, demand, and game structure are identical to those in the previous section. However, now, assume that multinational U prefers to purchase new inputs from DC rather than new inputs from LDC through technology transfer. Particularly, assume that the wages are the same in DC and LDC, and there is no transportation to ensure multinational U prefers the new inputs from DC.

Assumption 2. $w_{DC} = w_{LDC} = w$; $\tau_u = 0$.

Then, consider the situation that the policy-maker in LDC imposes an LCR, viz., γ^{LCR}, where $\gamma^{LCR} \in [0, 1]$, on multinational U, in the expectations of technology transfer by multinational U to local input suppliers that have only old technology and of technology spillover. Note that under Assumption 2, multinational U strictly prefers to purchase DC inputs, and outsources exactly γ^{LCR} from the LDC suppliers.

Defining $\phi \in [0, 1]$ as the portion of intermediate inputs produced through technology transfer of all the intermediate inputs produced in LDC, the quality of final goods produced by multinational U can be expressed as:

$$\lambda_U(\phi; \gamma^{LCR}) = (1-\gamma^{LCR})\lambda^{new} + \gamma^{LCR}\left[\phi\lambda^{new} + (1-\phi)\lambda^{old}\right]. \tag{9}$$

Eq. (9) differs from Eq. (1) because multinational U purchases an amount γ^{LCR} of intermediate inputs from LDC suppliers. Note that the amount of technology transfer by multinational U is $\phi\gamma^{LCR}$. Thus, defining $\rho \in [0, 1]$ as the fraction of quasi-new inputs that are purchased by local firm K of all the quasi-new inputs available through technology diffusion, the quality of final goods produced by local firm K can be expressed as:

$$\lambda_K(\phi, \rho; \gamma^{LCR}) = \rho\,\phi\gamma^{LCR}\lambda^{qnew} + (1-\rho\,\phi\gamma^{LCR})\lambda^{old}. \tag{10}$$

Clearly, Eq. (10) is similar to Eq. (2).

From the given technology and imposition of LCR, the marginal costs of production of the two final-good producers are:

$$mc_U(\phi) = (1-\gamma^{LCR})w_{DC} + \gamma^{LCR}(w_{LDC} + \phi(\theta+\psi)) = w + \gamma^{LCR}\phi(\theta+\psi)$$
$$mc_K = w,$$

where mc_i denotes the marginal cost of firm i.

Finally, assume that the two final-good producers play the following multi-stage game.

1. The policy-maker in the host country imposes the local-content requirement on multinational U in the host country.
2. Given LCR, multinational U decides whether it purchases the intermediate input from DC suppliers or LDC suppliers.
3. If multinational U purchases the intermediate input from LDC suppliers, the firm decides whether it transfers the superior technology to the selected local suppliers. If firm U decides to do so, it can produce the final goods with high quality, but technology diffusion can occur to the non-selected local suppliers. Also, multinational U chooses an amount ϕ of technology transfer.
4. Once technology diffusion occurs, the non-selected local suppliers can produce the quasi-new inputs, and the local final-good producer K can decide whether or not it purchases the quasi-new inputs. If firm K purchases the quasi-new inputs, it can produce a better final good than before. Otherwise, firm K continuously produces low-quality products. Further, firm K chooses an amount ρ for the adoption of the diffused technology.
5. Given the qualities of the two firm's final goods, the two firms compete against each other in Bertrand fashion.

[19] It should be noted that the theoretical conclusion of our paper supports the empirical findings of Xu (2000), as discussed in our introduction.

[20] Several studies argue that a host country's policy regarding FDI can act as a device that improves spillover. For example, Chun (2012) argues that government policy can make a multinational choose a spillover–carry entry mode.

[21] There are several studies regarding LCR (Chao and Yu, 1993; Davidson et al., 1985; Grossman, 1981; Hollander, 1987; Krishna and Itoh, 1988; Kwon and Chun, 2009; Lahiri and Ono, 1998; Lopez-de-Silanes et al., 1996; Qiu and Tao, 2001; Richardson, 1991). Most of these studies examine the welfare effect of LCR, and do not focus on the technology transfer that is due to the implementation of LCR. The only exception is Kwon and Chun (2009), who examine whether the implementation of LCR encourages technology transfer by the multinational from the developed country. However, they assume the automatic adoption of the diffused technology by local firms, and do not consider the strategic technology adoption of local firms.

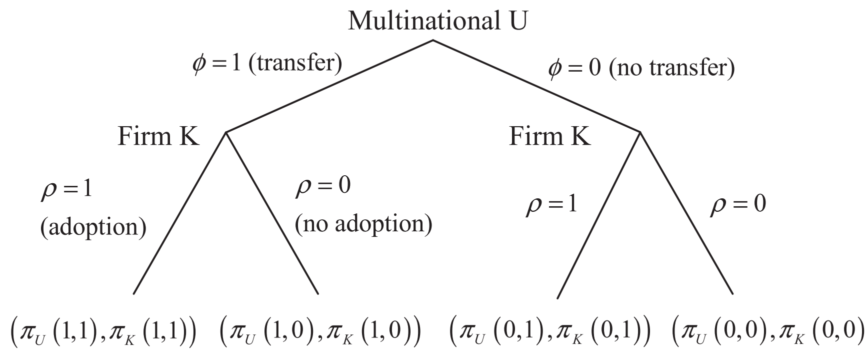

Fig. 2. The profit matrix.

Since we do not examine the optimal policy rule of a policy-maker, and assume that the multinational prefers to import new inputs from the home country, we can consider that the first two stages are predetermined. The remaining stages can be solved by backward induction.

6.1. Technology transfer and technology adoption

Note that assuming preference (4), the profit functions of the two final-good producers are the same as Eqs. (6) and (7). First of all, consider firm K's decision regarding technology adoption. As in the previous section, the profit function of local firm K is convex in ρ,[22] and the optimal choice of firm K is either $\rho=0$ or $\rho=1$. Similarly, the profit function of multinational U also is convex in ϕ,[23] and the optimal choice of multinational U also is either $\phi=0$ or $\phi=1$. Therefore, both firms can choose either 0 or 1 in the sequential game, and multinational U moves first. Fig. 2 and Table 2 show the game tree and the pay-off matrix of the game, respectively. Note that $(\phi=0,\rho=0)$ and $(\phi=0,\rho=1)$ are identical because the adoptable technology is not transferred by multinational U.

Suppose that multinational U transfers the new technology to local suppliers in the first stage of the game ($\phi=1$). The technology adoption rule of local firm K in the second stage of the game is:

$$\rho=\begin{cases}1 & \text{if } \Delta\lambda^{no}\geq\dfrac{\gamma^{LCR}(\theta+\psi)}{\sqrt{1-\gamma^{LCR}}}\\ 0 & \text{otherwise}\end{cases}. \tag{11}$$

Given the technology adoption rule of local firm K, viz., Eq. (11), consider the technology transfer rule of multinational U. From a comparison of the profits depicted in Table 2, we can derive the following decision rule:

$$\pi_U(\phi=0,\rho=1)\geq\pi_U(1,,,1)\ \text{for any }\Delta\lambda^{no}\text{ and }\gamma^{\mathrm{LCR}}$$
$$\pi_U(\phi=0,\rho=0)\geq\pi_U(1,,,0)\ \text{if }\Delta\lambda^{no}\in\left[\frac{\theta+\psi}{2}\left(1-\sqrt{(1-\gamma^{LCR})}\right),\frac{\theta+\psi}{2}\left(1+\sqrt{(1-\gamma^{LCR})}\right)\right].$$

First of all, note that if local firm K adopts the diffused technology in the second stage, multinational U does not transfer the new technology in the first stage, that is, $\pi_U(\phi=0,1)\geq\pi_U(1,1)$. Thus, $(\phi=1,\rho=1)$ cannot be a subgame-perfect Nash equilibrium. However, if local firm K does not adopt the diffused technology in the second stage, multinational U may or may not transfer the technology depending on the technological gap between the two countries and LCR. Thus, $(\phi=1,\rho=0)$ and $(\phi=0,\rho=0)$ can be a subgame-perfect Nash equilibrium depending on the sizes of $\Delta\lambda^{no}$ and γ^{LCR}.[24] Since technology spillover occurs only if $(\phi=1,\rho=1)$, which cannot be a subgame-perfect Nash equilibrium, the following proposition is obtained.

Proposition 2. *Given the structure of the game and the entry of multinational U in LDC, suppose that Assumption 2 holds. Then, at any subgame-perfect Nash equilibrium, there is no technology spillover from multinational U to local firm K in LDC.*

Proof. Although the technology-spillover occurs only if $(\phi=1,\rho=1)$, $(\phi=1,\rho=1)$ is not a subgame-perfect Nash equilibrium because $\pi_U(\phi=0,1)\geq\pi_U(1,1)$.Q.E.D.

Proposition 2 implies that even when multinational U transfers new technology to local input suppliers and local firm K can access the quasi-new technology through technology diffusion, local firm K will not use the advanced technology. Thus, firm K supplies low-quality products with old technology to avoid more intense competition due to the similar products of the two firms. Therefore, although multinational U transfers new technology to LDC firms, there is no technology spillover in LDC. Furthermore, Proposition 2 implies that if policy-makers in LDC introduce an LCR to encourage technology transfer and technology spillover, the LCR may encourage technology transfer because the decision rule of the multinational U to choose ϕ depends on γ^{LCR}; however, the LCR cannot serve to increase the technology level of the local producer. From the above discussion, Corollary 2.1 follows without further proof.

Corollary 2.1. *At any subgame-perfect Nash equilibrium, an LCR that is introduced by the policy-maker in LDC does not encourage technology spillover from multinational U, and cannot increase the quality of products produced by the local producer.*

Corollary 2.1 implies that *the LCR does not encourage technology spillover from the multinational* because the local final-good producer prefers to produce low-quality product and refuses to adopt the transferred technology.

Although an LCR does not encourage technology spillover, it can encourage multinational U to transfer new technology to local input suppliers. This can be proved by simple comparative statics of the technology decision rule of multinational U.

[22] The second derivative of the profit function of firm K is $\frac{2\cdot(\phi\gamma^{LCR})^4\cdot(\Delta\lambda^{qno})^2\cdot(\theta+\psi)^2}{9\cdot(\Delta\lambda^{no}(1-\gamma^{LCR})+\gamma^{LCR}\phi(\Delta\lambda^{no}-\rho\Delta\lambda^{qno}))^3}\geq 0$, since $\Delta\lambda^{no}-\rho\Delta\lambda^{qno}>0$.

[23] The second derivative of the profit function of multinational U is positive since $\Delta\lambda^{no}-\rho\Delta\lambda^{qno}>0$: $\frac{2\cdot(1-\gamma^{LCR})^2(\gamma^{LCR})^2\cdot(\Delta\lambda^{qno})^2\cdot(\theta+\psi)^2}{9\cdot(\Delta\lambda^{no}(1-\gamma^{LCR})+\gamma^{LCR}\phi(\Delta\lambda^{no}-\rho\Delta\lambda^{qno}))^3}\geq 0$.

[24] Either $(\phi=1,\rho=0)$ or $(\phi=0,\rho=0)$ can be a subgame-perfect Nash equilibrium because there exists some γ^{LCR} such that $\gamma^{LCR}(\theta+\psi)/\sqrt{1-\gamma^{LCR}}\in[(\theta+\psi)(1-\sqrt{(1-\gamma^{LCR})})/2,(\theta+\psi)(1+\sqrt{(1-\gamma^{LCR})})/2]$, where $\gamma^{LCR}(\theta+\psi)/\sqrt{1-\gamma^{LCR}}$ is the critical value of $\Delta\lambda^{no}$ in Eq. (11).

Table 2
The profit matrix of the game.

π_U; π_K		Firm K (follower)	
		$\rho = 0$ (no adoption)	$\rho = 1$ (adoption)
Firm U (first mover)	$\phi = 0$ (transfer)	$\frac{4(1-\gamma^{LCR})\Delta\lambda^{no}}{9}$; $\frac{(1-\gamma^{LCR})\Delta\lambda^{no}}{9}$	$\frac{4(1-\gamma^{LCR})\Delta\lambda^{no}}{9}$; $\frac{(1-\gamma^{LCR})}{9}\Delta\lambda$
	$\phi = 1$ (no transfer)	$\frac{[2\Delta\lambda^{no}-\gamma^{LCR}(\theta+\psi)]^2}{9\Delta\lambda^{no}}$; $\frac{[\gamma^{LCR}(\theta+\psi)+\Delta\lambda^{no}]^2}{9\Delta\lambda^{no}}$	$\frac{[2(1-\gamma^{LCR})\Delta\lambda^{no}-\gamma^{LCR}(\theta+\psi)]^2}{9(1-\gamma^{LCR})\Delta\lambda^{no}}$; $\frac{[(1-\gamma^{LCR})\Delta\lambda^{no}+\gamma^{LCR}(\theta+\psi)]^2}{9(1-\gamma^{LCR})\Delta\lambda^{no}}$

Proposition 3. *Given the structure of the game and the entry of multinational U in LDC, suppose that Assumption 2 holds. The policy-maker in LDC can encourage technology transfer from multinational U by imposing a stronger LCR.*

Proof. Since $\frac{\partial}{\partial\gamma^{LCR}}\frac{\theta+\psi}{2}\left(1-\sqrt{(1-\gamma^{LCR})}\right)>0$ and $\frac{\partial}{\partial\gamma^{LCR}}\frac{\theta+\psi}{2}\left(1+\sqrt{(1-\gamma^{LCR})}\right)<0$, multinational U is more likely to transfer the new technology to local input suppliers if the LCR becomes stronger. Q.E.D.

7. Concluding remarks

Over the last several decades, the inconsistent evidence regarding positive technology spillover has been one of the controversial topics of FDI. Among the many potential explanations for the lack of technology spillover, the more popular ones point to the heterogeneous absorptive capacity of local firms and the technological gap. However, it seems that our understanding is still incomplete regarding the roles of absorptive capacities and the technological gap in technology spillover because the strategic decisions by local firms to adopt diffused technology has been ignored in previous studies.

This study examines the role of local firms' strategic adoption of multinationals' technology in terms of technology spillover. To do so, we construct a simple theoretical model by combining the models of technology adoption and technology spillover through backward linkage. With this new model, we show that if the technological gap is large between the multinational and local firms, it is possible that the local final-goods producers will not adopt the diffused technology as they want to avoid competing with the multinational firm. Thus, even though the transferred technology is diffused and local firms have the capacity to absorb it, the technology spillover would not be observed. Furthermore, given the technological gap, when local firms have a greater absorptive capacity to absorb the diffused technology, the probability of technology spillover increases. Additionally, we apply the model to analyze the effect of local content requirements (LCR). The analytic result shows that LCR may fail to enhance technology spillover because these do not encourage technology adoption by local firms. Under LCR, here again, local firms may not adopt the diffused technology to avoid competing with the multinational firm in the local market.

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