Technology Transfer without the Spillover Effect from a Multinational in Strategic Competition

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Abstract

Considering the strategic choice of technology transfer by multinationals and technology adoption by local firms, we construct a simple theoretic model to analyze the spillover effect. Using the constructed model, we show that in some circumstances, the local final-good producer may not adopt the diffused technology to avoid severe competition with the multinational that produces better product, and the technology spillover effect does not occur even though the transferred technology is diffused to local firms. In addition, we apply the model to analyze the effect of local content requirement on technology transfer and technology spillover. The analytic result shows that LCR to enhance technology spillover may fail because the local firm may not adopt the diffused technology to avoid severe competition with the multinational in the final-good market.

Keywords: Quality competition, Technology adoption, Technology transfer, Technology diffusion, Local content requirement
JEL Classification: F13, F23, L12

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I. Introduction

Over the last several decades, the rapid growth of foreign direct investment (FDI) has been one of the most remarkable phenomena in the field of the international economics, and numerous studies have examined the determinants and effects of FDI. The existence of the technology spillover effect is one of the debated topics regarding FDI. As Aitken and Harrision (1999) mentioned in their study, the technology spillover effect, if it occurs, may increase the productivity of the host country of FDI. Thus, the existence of the technology spillover effect has been one of the reasons for host countries, especially developing countries, to attract multinationals to their economic territories. Naturally, scores of researchers have attempted to find evidence of the technology spillover effect and the transmission channel of technology spillover.[1]

Although the existence of the technology spillover effect has been widely perceived in public, academic research apparently has failed to find consistent evidence of the effect.[2] As expected in public, many studies show that FDI may entail an increase in productivity, and technology spillover may occur (Caves, 1974, for Australia; Globerman, 1979, for Canada; Blomström and Persson, 1983, for Mexico; Hejazi and Safarian, 1996, for OECD countries; Borensztein, Gregorio, and Lee, 1998, for 69 developing countries; Cheung and Lin, 2004, for China; Liu, 2008, for China; Javorcik and Spatareanu, 2008, for Romania[3]). However, other studies report either no evidence of the technology spillover effect or that FDI may result in a negative spillover effect (Haddad and Harrison, 1993, for Morocco; Lichtenberg and Van Pottelsberghe de la Potterie, 1996, for OECD countries; Aitken and Harrison, 1999, for Venezuela; Djankov and Hoekman, 1999, for the Czech Republic). Further, Xu (2000) reports that FDI into developed countries entails a positive technology spillover effect, but the spillover effect through FDI into developing countries is not clear from data on outward FDI from the US.

Thus, previous empirical results on the existence of the technology spillover effect are mixed and non-consistent. As Xu (2000) discussed, the limitations of the measurement of FDI and technology

[1] Saggi (2002) provides a good survey of the literature on the technology (or knowledge) spillover effect through foreign direct investment.
[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 knowledge spillovers from FDI."
[3] They showed that vertical spillovers are associated with projects with shared domestic and foreign ownership, but not with fully-owned foreign subsidiaries.

spillover might be possible reasons for the mixed results. Particularly, in most empirical studies, productivity is a poor proxy for measuring technology spillover. However, considering the channel for transmitting technology through FDI, the mixed results on technology spillover might be natural. Specifically, most previous studies ignore the strategic decision of the local firm that receives the diffused technology.[4] That is, those studies assume that the transferred technology can be diffused to local firms, and is adopted automatically by local firms. However, as discussed widely in the literature on industry organization, technology adoption is a strategic choice of firms, and it is possible that the diffused technology is discarded by local firms in strategic competition. Clearly, if the diffused technology is not adopted by local firms, the technology spillover effect is not observed. Surprisingly, no studies have incorporated this strategic decision of firms in the process of technology transfer, diffusion, and adoption. Thus, we employ the model of vertical product differentiation[5] as in Mussa and Rosen (1978)[6] to incorporate the strategic technology adoption into the process of technology transmission from a multinational to local firms.

In this paper, considering the strategic choice of technology transfer by multinationals and technology adoption by local firms, we construct a simple theoretic model to analyze the spillover effect. Particularly, we consider technology transfer and diffusion in vertical production, as in Pack and Saggi (2001). The new technology that a multinational from a developed country possesses can be transferred to selected local input suppliers in the host country and diffused to non-selected local input suppliers. Further, if it is necessary, a local final-good producer that is a competitor of the multinational in the host country can adopt the diffused technology[7]. The two final-good producers, viz., the multinational and the local final-good producer, compete with each other in the final-good market in terms of price and quality. Using the constructed model, we show that in some circumstances, the local final-good producer may not adopt the diffused technology to avoid severe competition with the multinational that produces better product, and the technology spillover effect does not occur even though the transferred technology is diffused to local firms. In addition, we apply the model to analyze the effect of policy that encourages the local production of intermediate inputs rather than importing from the home country of the multinational to enhance technology transfer and technology spillover: that is, local content requirement (LCR). The analytic result shows that LCR to

[4] Crespo and Fontoura (2006) studied the factors determining the existence, dimension, and sign of FDI spillovers. However, they did not consider the strategic choice of local firms.

[5] The consumer will buy the high-quality good when a high- and a low-quality good are offered at the same price. She will buy lower-quality goods only if they are offered at sufficiently lower prices.

[6] Recent analysis of US imports reveals a substantial number of imported products with various relative qualities. For example, Schott (2004) finds that across all US 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)

[7] 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.

enhance technology spillover may fail because the local firm may not adopt the diffused technology to avoid severe competition with the multinational in the final-good market.

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

II. 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.

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, 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 technology 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.[8] 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[9], 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.[10] 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 $\lambda^{qnew} \in \left[\lambda^{old}, \lambda^{new}\right]$. 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 $\Delta\lambda^{qno} \equiv \lambda^{qnew} - \lambda^{old} \geq 0$. The price of a quasi-new input is simply w_{LDC} since quasi-new input suppliers compete on the basis of price.

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

[8] 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).

[9] 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.

[10] 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.

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.

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

Given the technology, assume that the two final-good producers, multinational U and loc al 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:

$$mc_U^{LDC}(\phi) = \phi(w_{LDC} + \theta + \psi) + (1-\phi)w_{LDC} = w_{LDC} + \phi(\theta + \psi) \quad (3)$$
$$mc_K = w_{LDC},$$

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:

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

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:

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

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

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

III. Strategic Choices of Firms: Technology diffusion without the spillover effect

First of all, note that the profit function of local firm K, viz., Eq. (7), is convex in ρ [11], and the optimal choice of firm K is either $\rho=0$ or $\rho=1$. Further, the optimal choice of the multinational, U, for ϕ is simple because the profit function, Eq. (6), is strictly increasing in ϕ [12], and $\phi=1$. Thus, when multinational U decides to purchase local intermediate inputs, the firm transfers new technology to the selected local suppliers, and purchases new inputs from them. This is because the multinational prefers to occupy the market for high-quality product, and avoid competition with the local final-good producer in the low-quality product market. Table 1 shows the game tree and the pay-off matrix of the game. Note that $(import,\rho=0)$ and $(import,\rho=1)$ are identical because adoptable technology is not transferred by multinational U.

$\pi_U;\pi_K$		Firm K (Follower) $\rho=0$ (No adoption)	Firm K (Follower) $\rho=1$ (Adoption)
Firm U (First mover)	Local outsourcing and $\phi=1$ (Outsourcing)	$\frac{\left[2\Delta\lambda^{no}-(\theta+\psi)\right]^2}{9\Delta\lambda^{no}}$; $\frac{\left[\Delta\lambda^{no}+\theta+\psi\right]^2}{9\Delta\lambda^{no}}$	$\frac{\left[2\left(\Delta\lambda^{no}-\Delta\lambda^{qno}\right)-(\theta+\psi)\right]^2}{9\left(\Delta\lambda^{no}-\Delta\lambda^{qno}\right)}$; $\frac{\left[\Delta\lambda^{no}-\Delta\lambda^{qno}+\theta+\psi\right]^2}{9\left(\Delta\lambda^{no}-\Delta\lambda^{qno}\right)}$
	Import from home (Import)	$\frac{\left[2\Delta\lambda^{no}-\tau\right]^2}{9\Delta\lambda^{no}}$; $\frac{\left[\Delta\lambda^{no}+\theta+\psi\right]^2}{9\Delta\lambda^{no}}$	$\frac{\left[2\Delta\lambda^{no}-\tau\right]^2}{9\Delta\lambda^{no}}$; $\frac{\left[\Delta\lambda^{no}+\theta+\psi\right]^2}{9\Delta\lambda^{no}}$

Table 1. The profit matrix of the game.

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

[12] The profit of multinational U can be expressed as:
$$\pi_U(\phi,\rho)=\frac{\phi\left(2\left(\Delta\lambda^{no}-\rho\Delta\lambda^{qno}\right)-(\theta+\psi)\right)^2}{9\left(\Delta\lambda^{no}-\rho\Delta\lambda^{qno}\right)}.$$
Clearly, $\pi_U(\phi,\rho)$ is strictly increasing in ϕ.

Note that if $\pi_U\left(import\right) \geq \pi_U\left(outsourcing\right)$, multinational U prefers to import intermediate inputs from the home country to purchase domestically produced intermediate inputs. The decision of multinational U regarding imports versus domestic outsourcing depends on the transportation cost and training costs. Since our analysis focuses on technology transfer and diffusion rather than intrinsic advantage in production costs, assume the transportation cost is high enough, and that multinational U prefers to purchase domestically-produced inputs rather than home-produced inputs.

Assumption 1: $w_{DC} = w_{LDC} = w$; $\tau_U \leq 2\left(\Delta\lambda^{no} - \sqrt{\Delta\lambda^{no}\left(\Delta\lambda^{no} - \Delta\lambda^{qno}\right)} + \left(\theta+\psi\right)\sqrt{\dfrac{\Delta\lambda^{no}}{\Delta\lambda^{no} - \Delta\lambda^{qno}}}\right)$.[13]

Now, consider the strategic choice of local firm K at the second stage. From a comparison of the profits shown in Table 1, the following decision rule of local firm K can be obtained:

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

Note that if the diffused technology from multinational U is not adopted by local firm K, the technology spillover effect is not observed, because the diffused technology is discarded by local firm K. Then, the decision rule of local firm K can be rewritten as the following proposition (Proposition 1).

Proposition 1:
Given the assumptions, the structure of the game, and the entry of multinational U in LDC, there is no spillover effect of the transferred technology on the local final-good producer if $\Delta\lambda^{no} \geq \bar{\lambda}$. Otherwise, a spillover effect of the transferred technology on the local final-good producer occurs, where $\bar{\lambda} \equiv \frac{1}{2}\left[\Delta\lambda^{qno} + \sqrt{\left(\Delta\lambda^{qno}\right)^2 + \left(\theta+\psi\right)^2}\right]$.

Thus, given the structure of the game and the assumption of entry of multinational U in LDC, the local final-good producer does not adopt the diffused technology, and the technology spillover effect

[13] $\pi_U\left(import, \rho=0\right) \leq \pi_U\left(outsourcing, \rho=0\right)$ and $\pi_U\left(import, \rho=1\right) \leq \pi_U\left(outsourcing, \rho=1\right)$ if $\tau_U \leq 2\left(\Delta\lambda^{no} - \sqrt{\Delta\lambda^{no}\left(\Delta\lambda^{no} - \Delta\lambda^{qno}\right)} + \left(\theta+\psi\right)\sqrt{\dfrac{\Delta\lambda^{no}}{\Delta\lambda^{no} - \Delta\lambda^{qno}}}\right)$.

does not occur, if $\Delta\lambda^{no} \geq \bar{\lambda}$. The decision rule $\Delta\lambda^{no} \geq \bar{\lambda}$ implies that if the technology gap between the DC and LDC firms is large, firm K does not adopt the diffused technology, because the quasi-new technology may improve the quality of the final good but is not enough for competition with multinational U in terms of product quality. In this case, the local firm prefers to produce the current, low-quality product and occupy the market for low-quality products. However, if the technology gap is small, the local firm adopts the diffused quasi-new technology and competes with multinational U on quality. Proposition 1 implies that if the technology gap between DC and LDC is large, technology diffusion may occur, but the spillover effect does not occur. Note that many empirical studies on the existence of the spillover effect report that there is no evidence of the spillover effect via FDI from developed countries to less-developed countries (Xu, 2000). The theoretical result of our paper seems to concur with such empirical evidence, and suggests that technology transfer without the spillover effect might be a result of the strategic choices of firms.

Finally, note that $\bar{\lambda} > \Delta\lambda^{qno}$ by the definition; also, $\bar{\lambda}$ can be approximated in the form of $\Delta\lambda^{qno} + \alpha$, where α is some positive value. Further, assume that the quality of quasi-new inputs depends on the quality of the transferred new technology; define $\lambda^{qnew} \equiv \delta\lambda^{new}$, where $\delta \in \left[\lambda^{old} / \lambda^{new}, 1\right]$ represents the level of technology diffusion. Then, the decision rule $\Delta\lambda^{no} \leq \bar{\lambda}$ can be rewritten as $\Delta\lambda^{no} - \Delta\lambda^{qno} = (1-\delta)\lambda^{new} \leq \alpha$. This shows that if the diffused technology is good enough for local firm K to compete with multinational U in terms of quality, the local firm adopts the diffused technology. However, if the diffused technology is insufficient for local firm K to compete against the multinational in terms of quality, the local firm does not adopt the diffused technology, and wants to avoid competition on quality.

IV. Application: Local content requirements without a spillover effect

The previous section clarifies that technology transfer without spillover effects 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 spillover effects, can fail. 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[14].

[14] There are several studies regarding LCR (Grossman, 1981; Davidson et al., 1985; Hollander, 1987; Krishna and Itoh, 1988; Richardson, 1991, 1993; Chao and Yu, 1993; Lopez-de-Silanes et al., 1996; Lahiri and Ono, 1998; Qiu and Tao, 2001; Kwon and Chun, 2009). 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

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:

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

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:

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

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.

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:

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

$$mc_K = w,$$

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.

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.

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 [15], 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 [16], 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. Figure 1 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.

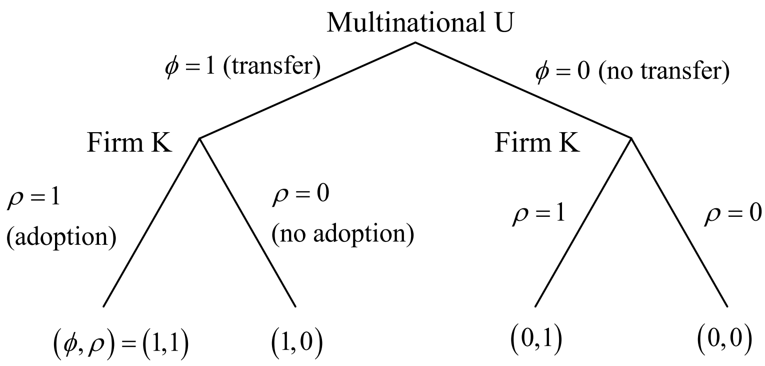

Figure 1. The game tree.

$\pi_U ; \pi_K$		Firm K (Follower)	
		$\rho = 0$ (No adoption)	$\rho = 1$ (Adoption)
Firm U (First mover)	$\phi = 0$ (transfer)	$\frac{4(1-\gamma^{LCR})\Delta\lambda^{no}}{9} ; \frac{(1-\gamma^{LCR})\Delta\lambda^{no}}{9}$	$\frac{4(1-\gamma^{LCR})\Delta\lambda^{no}}{9} ; \frac{(1-\gamma^{LCR})\Delta\lambda}{9}$
	$\phi = 1$ (no transfer)	$\frac{\left[2\Delta\lambda^{no} - \gamma^{LCR}(\theta+\psi)\right]^2}{9\Delta\lambda^{no}} ;$	$\frac{\left[2(1-\gamma^{LCR})\Delta\lambda^{no} - \gamma^{LCR}(\theta+\psi)\right]^2}{9(1-\gamma^{LCR})\Delta\lambda^{no}} ;$

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

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

		$\frac{\left[\gamma^{LCR}(\theta+\psi)+\Delta\lambda^{no}\right]^2}{9\Delta\lambda^{no}}$	$\frac{\left[\left(1-\gamma^{LCR}\right)\Delta\lambda^{no}+\gamma^{LCR}(\theta+\psi)\right]^2}{9\left(1-\gamma^{LCR}\right)\Delta\lambda^{no}}$

Table 2. The profit matrix of the game.

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 1, we can derive the following decision rule:

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

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 technology 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}.[17] 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:

[17] 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 $\gamma^{LCR}(\theta+\psi)/\sqrt{1-\gamma^{LCR}}\in\left[(\theta+\psi)\left(1-\sqrt{\left(1-\gamma^{LCR}\right)}\right)/2,(\theta+\psi)\left(1+\sqrt{\left(1-\gamma^{LCR}\right)}\right)/2\right]$, where $\gamma^{LCR}(\theta+\psi)/\sqrt{1-\gamma^{LCR}}$ is the critical value of $\Delta\lambda^{no}$ in Eq. (11).

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 effect from multinational U to local firm K in LDC.

Proof:

$(\phi = 1, \rho = 1)$ is not a subgame-perfect Nash equilibrium. 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 effect 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.

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

V. Concluding Remarks

Over the last several decades, the existence of the technology spillover effect is one of the debated topics regarding FDI. Furthermore, academic research apparently has failed to find consistent evidence of the effect. These inconsistent results might constitute a statistical problem due to inadequate data for measuring FDI and the technology spillover effect, as Xu (2000) discussed. However, from another point of view, the mixed results on technology spillover might be natural because technology transfer and adoption – which are a channel for transmitting new technology – are strategic choices of firms in strategic competition. In some circumstances, the local final-good producer may not adopt the diffused technology to avoid severe competition with multinationals that are producing better products, and the technology spillover effect does not occur even though the transferred technology is diffused to local firms. Furthermore, we apply the model to analyze the effect of policy that encourages the local production of intermediate inputs rather than importation from the home country of the multinational to enhance technology transfer and technology spillover – which is a local content requirement (LCR). The analytic result shows that the LCR to enhance technology spillover may fail because the local firm may not adopt the diffused technology to avoid severe competition with the multinational in the final-good market.

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