The Multinational Enterprise's Choice of Technology in LDCs with Potential Imitators

September 1998

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Abstract: This paper analyzes a multinational enterprise's (MNE's) choice of technology in a less-developed country (LDC) when it has a range of available technologies that it can incorporate into the production process. When the MNE faces potential imitators in the LDC, we show that the MNE may choose a technology that is either less advanced *or more advanced* than it would in the absence of potential imitation. A MNE may pick a more advanced technology in our model because imitation costs rise with the level of technology with the possibility of choosing a technology that makes local imitation prohibitive. This is a potential explanation for empirical findings that MNEs often employ much more capital-intensive processes in LDCs that appear inconsistent with the countries relative factor endowments. Importantly, we also explore the role of government policy and find that optimal policies are quite sensitive to parameters in our model, suggesting the difficulty of choosing an optimal policy in reality

JEL Classification: F23, O32, O38.

We thank Chris Ellis for helpful comments on an earlier draft. All errors or omissions are responsibility of the authors.

1. Introduction

Recent years have seen a growing literature concerning the phenomenon of technology transfer from multinational enterprises (MNEs) to a host country. This issue may be of particular importance for less-developed countries (LDCs) where technology transfer from MNEs can be a significant source of future growth and development. Numerous papers have focused on the choices and decisions of both major players in the issue of technology transfer from MNEs to LDCs. The MNE wants to make use of its firm-specific technology in search of its highest return, but is necessarily concerned with losing its advantage from unplanned technology transfer to potential rivals in the host country. At the same time, the LDC government wants to provide incentives for technology transfers to take place, assuming it increases welfare. These issues are often addressed in models exploring patent protection and enforcement by LDCs.

This paper looks at a three-stage strategic model of technology transfer by MNEs into LDCs. In the first stage, the MNE chooses whether to enter the LDC or not and chooses the level of technology if it decides to enter. Second, a potential imitating competitor in the LDC decides on its imitation efforts which lead to some possible "catchup" for the local competitor from an initially low level of technology. In the final stage, the two competitors compete in quantities where production costs are determined by their level of technology. From this basic structure, we incorporate a number of novel and empirically important features into the model. First, we assume that an MNE has a range of process technologies that it can employ in the LDC, from less-complex technologies to most-complex technologies.[1] As found by a number of

[1] Diwan and Rodrik (1991) is an example of a model that analyzes a MNE making a choice across a range of *product*, rather than process, technologies.

empirical papers, including Pack (1976), LeCraw (1977), Ansalem (1983), and Yeoman (1984), MNCs use technologies that can vary substantially from those employed in other subsidiary locations within the MNC and from that of local firms. This suggests that the level of technology chosen by an MNC is a choice variable. Second, following Wang and Blomstrom (1992), we model imitation by local firms as costly. However, we assume imitation costs are not only convex in effort, but also that the level of technology chosen by the MNC has an important impact on the costs of imitation. Specifically, the costs and marginal costs of imitation are increasing in the level of MNC technology. At the same time, higher technology leads to higher costs for the MNC in adapting its production technology to local conditions. For example, one could think of higher levels of technology requiring greater amounts of costly infrastructure, or alternatively greater worker training costs, where these costs increase at an increasing rate because of the quality of resources in the LDC. Thus, there is a tradeoff for a MNE in that a higher technology makes imitation more difficult, yet it increases costs of adapting the production process to local conditions.

Given these features, we focus on the MNC's strategic decision concerning which level of the process technology is optimal to employ in the host country. The features of our model lead to a wide array of potential outcomes. In particular, we show that a MNE may bring in either less advanced or more advanced technology in the face of imitation relative to the technology it would bring if no imitation was possible. For instance, it might bring in lower levels of technology to diminish losses from imitation (as well as adaption costs). On the other hand, it may bring in a very high level of technology, despite the high adaption costs, because it makes imitation prohibitively expensive for local imitators. In summary, the MNE's choice of technology, and even whether it enters the LDC or not, is sensitive to important parameters of the model.

These results may be a potential explanation for a number of previous empirical findings. First, as detailed below, there is substantial evidence that MNE technology in LDC countries vary considerably across firms' locations and that MNE technologies often vary substantially from that of local firms. Empirical studies (e.g., Ansalem,1983, and Yeoman, 1984) have been puzzled that MNE technology often seems too advanced or capital-intensive relative to capital availability and local conditions. This evidence is consistent with our model where MNEs strategically alter their technology depending on local conditions and the possibility of imitation by local competitors. In fact, it is consistent with our result that for some range of parameters it makes sense to deter imitation in the LDC by employing an "unattainable" technology.

Whereas almost all previous work in this area has had unambiguous policy conclusions, the obvious policy implications from our model is that optimal government policies by LDCs are quite sensitive to the nature of imitation costs by local firms and adaption costs for MNEs. We examine a number of alternative policies that a host LDC could pursue, including the degree of patent enforcement, taxes or subsidies on imitation by the local enterprise, and taxes or subsidies on the MNE's cost of adapting technology to local conditions. In all cases, we show that the policy is very sensitive to the nature of the game. This carries the important message that identification of optimal policies by a host country may be next to impossible in reality. At the very least, it implies that there are no policies that are generally optimal.

2. Literature Review

2.1 Empirical Literature

The empirical evidence on the choice of technology by MNEs to LDCs is quite mixed. As Findlay (1978b) notes, there is belief and evidence that MNEs often restrict the transmission of technology to LDCs, yet there is also belief and evidence that MNEs use technology that is "inappropriate" for LDCs given their relative factor proportions. Some work in this area, including Pack (1976), LeCraw (1977), Ansalem (1983), and Yeoman (1984) show that the choice of technology by MNEs in LDC varies substantially across firms, industries and countries. For example, Ansalem finds that technologies used in textile and paper and pulp industries cover a wide range across firms in the same LDC. The surprising result is that the technologies in these industries in the LDCs seem too capital-intensive given the relative labor abundance and capital scarcity of the countries. Ansalem attributes this to the fact that technology and equipment for production comes from more advanced MNEs, which leads him to recommend policies to facilitate more labor-intensive, and presumably more efficient, processes for local firms in LDCs. Yeoman (1984) finds that MNEs often do not adapt their technology process to take into account local factor market prices in industries such as pharmaceuticals, and heavy machinery and equipment. This seems consistent with Ansalem's evidence on technologies used in textiles and paper and pulp. However, Yeoman finds quite the opposite for small appliance MNEs, who adapt their processes much more readily to local conditions. In addition, Yeoman finds significant variation in adaption of technology across firms, even in the industries that generally do not adapt technology to local conditions. From these studies, a puzzle arises as to why there is so much variation in adaption by MNEs to local market conditions. By considering strategic interactions between MNEs and local firms under various assumption about imitation and spillovers, our model below will provide a possible explanation to this puzzle.

Mansfield and Romeo (1980) provide a number of other empirical insights on technology transfer by MNEs by interviewing and surveying senior executives of MNEs. Their evidence shows that unintentional leakage (or spillover) is an issue that concerns MNEs. First, they find evidence that the technology transferred voluntarily by MNEs is a function of their business relationship with the other party. Transfers of newer technology occur primarily within the firm from a parent to a subsidiary, whereas joint venture operations and licensees receive older technologies. This is consistent with the hypothesis that MNEs behave strategically when facing possible spillovers. Second, in about one-fourth of the cases of technology transfer they analyzed, the firm's executives felt that involuntary leakages because of the transfer hastened the foreigners' access to the technology by at least two and one half years. Importantly, the interviewed executives also felt that involuntary spillovers were much more prevalent with process technology, rather than new product technology or innovation. This motivates why our model below analyzes technology transfer of process technology to the LDC.

2.2 Theoretical Literature

A large number of theoretical papers have considered the subject of technology transfer from subsidiaries of MNEs in LDCs. Many papers refer to articles by Findlay (1978a) and Koizumi and Kopecky (1978; 1980) as early efforts to formalize the issues involved with technology transfer by MNEs.[2] Findlay develops a dynamic model of technology transfer by a

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[2] Ferrantino (1991) examines the choice of technology used by MNEs which are based in LDCs, rather than ones based in advanced countries, as is the focus here.

MNE with a number of important features. First, Findlay notes the possibility of spillovers from the MNE to the domestic firms in the host country and models this as a "contagion" effect, where the greater the exposure to the MNE, the more spillovers the domestic firms experience. In addition, provided the gap between the MNE's technology and that of the domestic firms is not too large, the "catch-up" by the local firms is increasing in the size of the gap. But interestingly, one of the possible results in Findlay's model is that the faster the rate of progress in MNE technology, the *lower* the eventual degree of technology development of the host country.

Some of the simplifying features of these earlier models, including Findlay's, is 1) costless spillovers without imitation efforts or costs on the part of the domestic firms, and 2) no consideration of strategic gaming by the MNE in its choice of technology or the host country in its choice of related policy instruments.

Das (1987) examines the strategic effects that imitation by firms in the host country (a spillover externality) may have on investing MNE behavior, including price, output, and choice of technology effects. Das considers a model with a price leader MNE that has a subsidiary in a country with a competitive fringe of domestic firms who gain from process technology spillovers. In the spirit of Findlay (1978a), these spillovers are increasing in the activity (proxied by output) of the MNE subsidiary. Solving for the optimal strategy of the MNE over time, Das finds that the MNE does not produce as much as it otherwise would without the presence of the domestic firms because of the spillovers. This is a classic spillover result, which will be in contrast to our results below. With respect to the optimal technology strategy for the MNE, Das actually finds it still is better for the MNE to transfer a better technology to its subsidiary despite spillovers because the gain to the subsidiary from cost savings is larger than the spillover losses. However, this is obviously related to the simple functional forms he uses to help ease analysis of the dynamic model used. In addition, there are a number of assumptions that Das employs that are potentially important for the results his model generates. First, like the earlier literature, spillovers (or imitation) are assumed to be costless. Second, spillovers are related to economic activity of the subsidiary, not the level of technology used. Finally, Das does not consider the potential impact the spillover externalities may have on the MNE's initial entry decision.

Wang and Blomstrom (1992) use a slightly different model to analyse similar issues to Das. While they relax some of the restrictive assumptions with Das' model, they generate quite similar results. Like Das, Wang and Blomstrom analyse a dynamic model where MNEs decide what level of technology to transfer to their subsidiary in an LDC where imitation spillovers to domestic firms are possible. Unlike Das, they explicitly model both the costs of technology transfer for the MNE (older, less-advanced technologies are less costly to transfer) and the costs of imitation for the domestic firms, which are convex in the imitation investment made by the domestic firm. Despite addition of these important features, their results are in the same spirit as Das, in the sense that they find that there are important incentives for MNEs to transfer their more advanced technology to the host country despite the spillover externalities. In particular, Wang and Blomstrom show that greater imitation efforts in the domestic industry increases the rate of technology transfer by the MNE. The intuition behind this is that the MNE races to stay ahead of the domestic firms. The policy conclusion they draw from this is that domestic governments should encourage local imitation efforts.

One of the more recent papers in this area, Muniagurria and Singh (1997), draws much different policy proscriptions. Muniagurria and Singh build a model that starts with the well-known work of Spencer and Brander (1983) on international R&D rivalry. They next make this model appropriate for analysing technology transfer between MNEs and LDC firms by having the two firms differ in that one is more advanced (in that it can generate R&D more efficiently) and technology spillovers are possible from the advanced to the less advanced firm. The firms play a game in R&D expenditures that reduce production costs. In such a game they find that optimal government policy for the LDC depends crucially on the environment of the game and tradeoffs between opposing effects. Higher R&D investment by the advanced foreign firm leads to greater spillovers to the less-advanced local firm – this is the spillover effect. However, higher R&D investment also leads to lower R&D efforts by the local firm because of the standard strategic reactions in a Nash game the firms are playing – this is the strategic effect. Thus, the optimal government policy is to encourage higher R&D investment by the advanced foreign firm if the spillover effect dominates the strategic effect, but discourage it if the strategic effect dominates the spillover effect.

3. Model

We analyse the technology choice of an MNE locating into LDC with a model of duopoly competition in quantities between a foreign MNE and a local enterprise (LE). On the demand side, for simplicity, we assume a linear inverse demand curve, P = (Q), where P is the market price received for the good, and $Q = q_L + q_M$, where q_L, q_M are quantities produced by the LE and MNE, respectively. We make the standard assumption that market price is decreasing in quantity supplied by the enterprises. The cost side is characterised by constant marginal costs. Similar to Das (1987), we assume production costs are a function of the firm's level of technology. Thus, constant marginal costs in our model are $c(\theta_i)$, where θ_i is the level of technology for each enterprise i=L (for LE),M (for MNE). We make the assumption that the cost function is twice differentiable and costs are decreasing in technology at a decreasing rate: $\partial c/\partial\theta < 0$, $\partial^2 c/\partial\theta^2 < 0$.

The basic model is a three-stage game, where in the first stage the MNE decides the level of technology (θ_M)from a continuous range of process technologies it has available and the two enterprises play a game in quantities. In other words, the MNE chooses $\theta_M \in [\underline{\theta}, \bar{\theta}]$, where $\underline{\theta}$ and $\bar{\theta}$ represent the lower- and upper-bound of the MNE's known and available technologies. In reality, there is some cost associated with a MNE adapting the chosen technology to the conditions in the host country. We assume that this cost is increasing in the level of technology at an increasing rate. This seems appropriate for the situation we model here since presumably higher levels of technology require more sophisticated infrastructure and/or significant amounts of specialized and skilled labor, which LDCs generally lack. We let $T(\theta)$ designate this adaption cost function for the MNE, which is assumed to be a twice differentiable function, where $\partial T/\partial\theta > 0$, $\partial^2 T/\partial\theta^2 > 0$,.

In the second stage of the game the LE decides whether to engage in costly imitation of the MNE's technology. Our treatment of the imitation process for the LE is quite different from previous work in this area and is important for the results we draw from the model. We assume the LE must choose an effort level, e, for its imitation process that directly leads to the LE closing the technology gap between its technology and that of the MNE by the proportion α. Thus, the LE's technology after imitation becomes

$$\theta_L + \alpha(e)(\theta_M - \theta_L), \qquad \textbf{(1)}$$

where $\alpha(e)$ is an increasing function in e. It is assumed that $\alpha(e) \in [0,1]$for any values of e in equilibrium. The lower bound rules out effortless technology improvement by the LE (e.g., through indirect spillovers) and the upper bound assures that the LE will not be able to develop a technology through the imitation process that betters the MNE's technology level. For simplicity, we assume that the LE's initial level of technology, θ_L, is predetermined before the start of the game.

Importantly, we assume that imitation is not just costly, but increasingly costly in the level of technology introduced by the MNE. Thus, we model the imitation cost function for the LE as dependent on not only the level of effort, but also on the level of MNE technology the LE is trying to imitate. More precisely, the imitation cost function is represented as $K(e,\theta_M)$, where $K(0,\theta_M)=0$, $\partial K/\partial e > 0$, $\partial^2 K/\partial e^2 > 0$, $\partial K/\partial \theta_M > 0$, $\partial^2 K/\partial e \partial \theta_M > 0$. The latter two properties explicitly model not only increasing imitation costs in the level of the MNE's technology, but that a higher level of θ_L also makes effort more costly. This is an important difference between our paper and previous work in this area and will be important for the conclusions we draw, but is one we believe is empirically plausible.

Finally, in stage 3 of the game the enterprises play a game in quantities to supply a third-country export market.[3] We focus on the subgame-perfect Nash equilibrium and solve the model backwards. Thus, we begin by describing stage 3.

3.1 Stage 3

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[3] Muniagurria and Singh (1997) make the same assumption to simplify welfare analysis. We employ this assumption for the same reason, but also discuss implications of relaxing this assumption at the end of section 5.

In the third stage the enterprises play a Nash game in quantities, given the level of technology chosen by the MNE in the first stage of the game (θ_M) and the level of effort, and hence degree of imitation ($\alpha(e)$) by the LE, in the second stage. Thus, given the discussion above, the enterprises' objective functions are the following:

$$\underset{q_i}{\text{argmax}}\ \Pi = P(Q)\,q_i - C_i\,q_i \qquad \text{where } i = L,M. \tag{2}$$

From the earlier discussion, $C_M = C(\theta_M)$ and $C_L = C[\theta_L + \alpha(e)(\theta_M - \theta_L)]$, and importantly, all parameters determining C_L and C_M have been chosen in previous stages and are invariant to decisions made by the firms in stage 3. First-order conditions for equations represented in (2) are:

$$P(.) + \frac{\partial P}{\partial q_i} - C_i \equiv 0 \tag{3}$$

Assuming that the standard second-order sufficient conditions for stability in this game are satisfied, we can solve for the Nash equilibrium quantities in terms of the parameters,

$$q_L^*(\theta_L,\theta_M,e) \text{ and } q_M^*(\theta_L,\theta_M,e). \tag{4}$$

From this, one can easily derive the following comparative static results: $\partial q_L^*/\partial\theta_L > 0$, $\partial q_L^*/\partial\theta_M < 0$, $\partial q_L^*/\partial e > 0$, $\partial q_M^*/\partial\theta_L < 0$, $\partial q_M^*/\partial\theta_M > 0$, $\partial q_M^*/\partial e < 0$. These results are easy to interpret since all three parameters only affect the enterprises' cost functions directly. For example, a higher level of technology for the LE, θ_L, lowers the LE's marginal cost, ceteris paribus, and means it will supply a higher quantity, while the MNE will supply a lower quantity, in the Nash equilibrium. A similar interpretation applies to the other comparative static results.

3.2 Stage 2

In the second stage, the LE chooses the level of effort it will use to imitate given the chosen technology by the MNE. Thus, the LE's problem in the stage 2 is the following:

$$\underset{e}{\text{Max}}\ \Pi_L = P(Q^*(.))\,q_L^*(.) - C_L[\theta_L + \alpha(e)(\theta_M - \theta_L)]\,q_L^*(.) - K(e,\theta_M), \qquad \textbf{(5)}$$

where $q_L^*(.)$ and $q_M^*(.)$ are as defined above and $Q^*(.)=q_L^*(.) + q_M^*(.)$. Differentiating (5) with respect to e and simplifying by use of equation (3), we get the following first-order condition:

$$P^{\prime}\frac{\partial q_M^*}{\partial e}q_L^* - C^{\prime}\frac{\partial \alpha}{\partial e}(\theta_M - \theta_L)\,q_L^* - \frac{\partial K}{\partial e} \equiv 0 \qquad \textbf{(6)}$$

Equation (6) has three terms which all have an intuitive interpretation. The first two terms can be signed as positive, given the assumptions and results above, and represent the gains the LE gets from increased effort and imitation, leading to lower costs. The first term reflects the indirect strategic gain from lower costs for the LE in its product market competition with the rival MNE. The second term represents the direct gains the LE receives from lower costs. The final term is negative and represents the additional imitation costs incurred for greater effort. Provided that either α is increasing in e at a decreasing rate ($\partial^2\alpha/\partial e^2 < 0$), or that the costs of effort increase at an increasing rate ($\partial^2 K/\partial e^2 > 0$), the second-order sufficient conditions can be satisfied for stability of the game. Provided these hold, we can solve for the LE's optimal choice of $e=e^*(\theta_L,\theta_M)$.

Before proceeding to discussion of the MNE's optimal choice of technology in stage 1, it is instructive to look at the comparative statics from this stage as well; in particular, the effect of MNE's technology choice on the LE's effort in this model. By Cramer's rule, we can derive:

$$\frac{\partial e^*}{\partial \theta_M} = \frac{-(-C^{/}\alpha(.)q_L^* - \partial K/\partial \theta_M)}{D}, \qquad \textbf{(7)}$$

where D is the determinant of the Hessian, which is assumed negative in order to satisfy second-order sufficient conditions. Both numerator terms in brackets can be signed as positive, which means the comparative result is ambiguous and represents an important tradeoff between two effects. When the MNE picks a higher level of technology (θ_M) the technology gap between the two enterprises is larger and the LE's imitation efforts receive greater rewards. This is captured by the first term in brackets in the numerator. However, a higher level of the MNE technology also raises costs of LE imitation in general, which is captured by the last term in brackets. If the latter effect dominates, then higher levels of MNE technology discourage the LE from expending effort on imitation (i.e., $\partial e^*/\partial \theta_M < 0$), whereas if the former effect dominates, then the LE is encouraged to imitate by higher chosen levels of technology by the MNE ($\partial e^*/\partial \theta_M < 0$). This obviously has implications for the MNE's choice of technology in stage 1. Before turning to discussion of stage 1, we note that $\partial e^*/\partial \theta_L$ can be unambiguously signed as positive; i.e., for this model, a higher level of initial technology by the LE leads to greater effort, ceteris paribus.

3.3 Stage 1

In the first stage, the MNE chooses whether to enter the market, and if it does, what level of technology it will use in the host market. If the MNE chooses not to enter the host market, it produces in its own home market with assumed higher production costs, but no possibility of any imitation by the LE. In this case, the MNE and LE still compete for a third export market (as in stage 3) and the MNE will get its profit in this case, which we label as $\hat{\Pi}$. If the MNE decides to locate production in the host country, the MNE's problem, knowing the upcoming decision process of the LE and the product market competition, is the following:

$$\underset{\theta_M}{\text{Max}}\ \Pi_M = P(Q^*(.))\,q_M^*(.) - C_M(\theta_M)\,q_M^*(.) - T(\theta_M), \qquad \textbf{(8)}$$

where all variables are defined as above, and remembering that T(.) is the cost function connected with adapting a certain technology to local conditions in the host market and is convex in the level of technology. Differentiating (8) with respect to θ_M and simplifying by use of equation (3), we get the following first-order condition:

$$P' q_M^* \frac{\partial q_L^*}{\partial \theta_M} + P' q_M^* \frac{\partial q_L^*}{\partial e^*} \frac{\partial e^*}{\partial \theta_M} - C' q_M^* - \frac{\partial T}{\partial \theta_M} \equiv 0 \qquad \textbf{(9)}$$

Equation (9) has four terms which will determine the MNE's choice of technology should it choose to enter. The first term reflects the strategic effect the MNE's technology choice has on its product market competition with the LE, while the second term is the strategic effect the MNE's technology choice has on the LE's imitation effort, which also ultimately affects the profits the MNE gets from its product market competition with the LE. The third term is the direct effect of the MNE's technology choice on its own production costs and the final term is the effect on the MNE's costs of adapting the technology to local conditions. Equation (9) will be important for our analysis of various scenarios below.

Provided the second-order sufficient conditions are satisfied, we can solve for the MNE's optimal level of technology $\theta_M=\theta_M^*(\theta_L)$ and optimal profits, $\Pi^*(.)$. Whether the MNE chooses to enter the host market then depends on whether the simple entry condition, $\Pi^*(.) > \hat{\Pi}$, is satisfied. We'll assume for the majority of the analysis below that this entry condition is satisfied.

4. The MNE's optimal technology choice

With the basic framework of our model and its properties established in the previous section, we now proceed to analyse the MNE's entry decision and optimal choice of technology for use in the host country under various model assumptions**.**

4.1 Case 1: No imitation possible by LE

The simplest case to analyse is where there is no imitation possible by the LE; in other words, stage 2 is eliminated from the game. This is a useful case to analyse as a base case for comparison against scenarios that involve imitation.[4] In this case, equation (9) becomes:

$$P'q_M^* \frac{\partial q_L^*}{\partial \theta_M} - C'q_M^* - \frac{\partial T}{\partial \theta_M} \equiv 0 \tag{10}$$

The difference between equations (9) and (10) is that the second term in (9) is eliminated. Thus,

[4] Below we will consider the case where the host government can effectively block imitation efforts by the LE through strict and complete patent protection for the MNE.

the MNE does not consider strategic effects of possible imitation. We will designate the optimal level of technology chosen by the MNE under this scenario as θ_M^0. For sake of comparison, we'll assume that, given the parameters of the model, the entry condition is satisfied for the MNE when there is no imitation and it locates production in the host market.

4.2 Case 2: Imitation possible by LE

When imitation is possible, equation (9) will determine the optimal level of technology chosen by the MNE if it enters the host market. As noted, equation (9) differs from (10) in the additional strategic effect which arises when imitation by the LE is possible. The sign of this additional term determines whether the optimal level of technology chosen by the MNE will be higher or lower than when imitation is not possible. Common wisdom may suggest that the MNE would bring in a lower technology in the presence of imitation to lower the potential rents for the imitator. On the other hand, Wang and Blomstrom (1992) find the MNE brings in higher technology over time when facing imitators. However, we find that both scenarios are possible in our model -- the possibility of imitation may lead to the MNE choosing a lower or higher level of chosen technology by the MNE than when there is no imitation possible by the LE. Mathematically, this result depends on the second term in equation (9), that captures the strategic effect from LE imitation efforts, because the sign of $\partial e^*/\partial\theta_M$ is ambiguous. As discussed above, the MNE's choice of technology affects the LE's imitation efforts in two opposing ways. On one hand a greater gap between the two enterprises' levels of technology means potentially larger rewards for the LE's effort and thus encourages effort. This has been highlighted by previous studies, beginning with Findlay (1978a). On the other hand, a higher level of MNE technology raises costs of LE imitation in general. Therefore if the technology gap effect is stronger than the higher imitation cost effect, then $\partial e^*/\partial\theta_M > 0$. This means the strategic effect in (9) is negative and the optimal choice of technology by the MNE is one that is lower than θ_M^0. However, if the imitation cost effect of a higher technology dominates the technology gap incentive, then $\partial e^*/\partial\theta_M < 0$, and it can be shown that the MNE picks a higher level of technology than θ_M^0. The intuition of the latter effect can be seen by thinking of a situation where a MNE picks a technology so advanced that the LE has no hope of possibly imitating it in the forseeable future. In this case, one could think of the cost of imitating activities for the LE being infinite.

To show this more intuitively, figures 1 and 2 depict scenarios (i.e., alternative sets of model behavioral parameters) where a MNE may pick a higher or lower level of technology, respectively, when faced with imitation. For each figure, the top panel shows the MNE's profit function, Π_M^0, and optimal choice of technology, θ_M^0, without imitation. The profit function is concave given our assumptions on the effect of technology on production and adaption costs. The optimal point on the profit function must be higher than the profit it could receive by locating production elsewhere in order for the entry condition to be satisfied. The dashed line at the far right of the functions depicted in the panel represents the highest level of technology available to the MNE, $\bar{\theta}$, whereas the origin of the horizontal axis is the lowest level of technology available, $\underline{\theta}$. From this starting point, figures 1 and 2 represent two different scenarios associated with imitation by depicting the loss an MNE suffers from imitation by the LE, which we denote in the middle panel of each diagram as L_M. This loss function is represented by the second term in equation (9). The loss function in figure 1 represents a situation where the cost of imitation for the LE increases quite substantially for higher levels of MNE technology, eventually getting prohibitive so that for a high enough level of technology the LE does not imitate and the MNE's loss function at that level of technology is zero. This is represented in the middle panel of figure 1 as the L_M function's intercept point along the horizontal axis. The MNE's optimal profit function in this situation is $\Pi_M^0 - L_M$, which we denote as Π_M^1. Graphically, taking the vertical sum of the top and middle panel in figure 1, we show Π_M^1, the MNE's profits with imitation by the LE, in the lower panel of figure 1. As graphed, this situation leads to an optimal level of MNE technology that is higher in the presence of imitation than without imitation. Intuitively, the MNE can choose a high enough level of technology to stop the LE from even attempting to successfully imitate and yet not suffer too much additional costs (or inefficiencies) from adapting the high level of technology to local conditions.

Figure 2 begins with the same MNE profit function without imitation in the top panel, but depicts a situation where the loss from imitation increases over the relevant range of technology (though at a decreasing rate). This is a case where the positive "technology gap" effect is never completely eliminated by the increasing costs of imitation on the margin. As graphed on the bottom panel of figure 2 this leads to an optimal choice of MNE technology that is below the technology it would choose without imitation. Intuitively, the MNE is picking a lower level of technology because the catchup by the LE is so strong as one increases the level of technology.

These scenarios and analytic solutions above assume the MNE's entry condition is satisfied, but it is important to remember that potential imitation efforts by the LE likely reduces the MNE's profitability and makes it less likely that the entry condition will be satisfied.[5] This

[5] The potential of imitation may not affect the optimal MNE profit, if the cost of imitation for the LE becomes prohibitively for low enough levels of MNE technology. One can see this in figure 1, by considering the possibility that the L_M function's intercept with the horizontal axis

possibility has rarely been noted,[6] but may be highly relevant in the real world. In fact, this may be at least a partial explanation for the puzzling empirical fact that the majority of foreign direct investment flows occur between developed countries instead of flowing from developed countries to LDCs, as standard trade theory suggests. Certainly, MNEs experience losses from imitation in developed countries as well. However, the imitation losses may be more important on the margin for MNEs considering investment in LDCs than for investment in developed economies. In addition, investment in a developed country may bring technology spillovers that go both ways between the MNE and the local competitors, whereas investment in an LDC only brings technology spillovers from the MNE to the local competitor.

The results we obtain stem primarily from the way we model how the MNE's technology choice affects the costs of imitation, and hence the imitation efforts of the LE. However, let us suggest other plausible alternative ways the model could generate similar results to suggest the plausibility and generality of our conclusions. One alternative formulation would be to make the degree of LE imitation success, captured by the variable $\alpha(.)$, decreasing in the level of the MNE's level of technology. In this formulation, one could think of $\alpha(.)$ as an expected level of success over two probabilistic events: failed imitation and successful imitation. The probability of successful imitation, p, and the probability of failure, 1-p. Success of imitation may be less likely the higher the MNE's level of technology, so that p is a decreasing function of θ_M. It is easy to

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could occur at a level of technology below θ_M^0. In this case, it is easy to see that the MNE would pick θ_M^0 and make the same level of profits as without any possibility of imitation. The potential of imitation could not lead to *higher* levels of profit for the MNE over the no-imitation scenario, given our model's assumptions.

[6] One exception is Muniagurria and Singh (1997), who mention the possibility of an entry condition in a footnote.

see that one could yield similar results from such a model and it may be just as realistic an assumption as the one we make above.

A second alternative formulation is to consider the advantage an MNE may have over an LE in obtaining a favorable cost of capital. Lending rates by financial institutions in LDCs tend to be quite high compared to world rates and smaller LEs often are not able to obtain financing on world markets. This imperfection in capital markets has potentially important consequences in the MNE's choice of technology when imitation is possible. If higher levels of technology correspond with higher levels of capital intensity in production, it is possible that at some point, higher levels of imitation by the LE will actually lead to higher costs of production. In essence, higher levels of technology makes the LE more efficient, but in turn, makes it substitute labor for more costly capital. We do not model these factor market considerations here, but again, this alternative formulation would lead to similar conclusions to the ones we present above. That is, the potential of imitation can significantly alter an MNE's technology choice, but whether the MNE brings in a lower or higher level of technology than would otherwise be the case is not certain![7]

5. Role for government policy?

If the entry decision and choice of technology by an MNE into an LDC is a strategic decision as modeled here, one ultimately would like to know what role an LDC government may

[7] One other consideration with labor markets is that a significant reason for a MNE to invest in a LDC is to access cheap labor. If higher levels of technology are correlated with higher levels of capital intensity, this may limit how high a level of technology a MNE would want because it cheap labor costs would no longer be as important. This consideration could be built into the model and could potentially reduce the likelihood of seeing the MNE raise its technology in the presence of imitation higher than the non-imitation case, but does not eliminate this possible case.

be able to play in order to increase welfare in the LDC. A simple way to model it here is to assume that the LDC government can commit to policies directed at either the MNE or the LE before the game described above begins. In this context a number of policies can be examined. We'll briefly examine three different ones, including patent protection for the MNE, and a tax or subsidy on imitation efforts by the LE, and a tax or subsidy for MNE adaption costs. We will assume that the government is choosing policy to maximizing welfare in the LDC. Because we assume both firms export all production, there is no domestic consumption in the host LDC market and, thus, country welfare is defined by the LE's profits plus any revenues or costs generated by the government policy.[8] For convenience we assume that the labor market is perfectly competitive, so that the derived labor demand from these firms does not affect the economywide wage, nor is there any union power to bargain away rents from the LE or MNE.

As alluded to above, we will consider three main policies: 1) complete patent protection for the MNE which eliminates imitation efforts by the LE over the period we are considering,[9] 2) a tax or subsidy for MNE adaption costs, and 3) a tax or subsidy on imitation efforts by the LE. While it is difficult to characterize all the possible outcomes from certain policies, this section intends to show an array of possible scenarios which show that optimal policy depends very crucially on the parameters of the game.[10]

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[8] Below we briefly discuss how optimal government policy is affected when some production is for host country domestic consumption as well.

[9] By complete patent protection we obviously imply a number of strong assumptions, including the ability to patent the particular technology without ambiguities and perfect and immediate enforcement of that patent.

[10] Consideration of a repeated game with a more dynamic focus than this model goes beyond our analysis. Obviously, these considerations may change what would be optimal in

5.1. Policy 1 – Complete patent protection

We begin with the first possible policy option, elimination of imitation efforts due to complete patent protection. To model this, assume that under this policy α(e), the proportion of the technology gap eliminated by the LE for a given level of effort (e), is zero for all values of effort. In this case, with positive costs of effort, it is trivial to show that the LE will choose e=0. At first glance, one would expect that the LE would be worse off from this policy (with the MNE better off), which is true over a certain range of parameter values. Intuitively, this policy means the LE cannot lower its costs whatsoever through imitation which would decrease its profits in the Cournot game with the MNE, everything else equal. Thus, the optimal policy for the LDC government would be to have lax patent enforcement to allow the LE to imitate as much as warranted.

On the other hand, we can show that complete patent protection increases the LE's profits for certain parameter values. To see this, one need only refer back to the scenario depicted in figure 1. With no imitation possible, the LE's level of technology, and hence, costs stay the same. However, with possible imitation, the LE's level of technology also stays the same. This is because the MNE chooses a technology high enough to discourage the LE from imitating. In contrast, the MNE's technology choice is higher (and hence, its costs lower) when imitation is possible than when it is not. Thus, the possibility of imitation means lower LE profits than if the LE government enforces complete patent protection so that the MNE knows imitation is not possible. In this case, the MNE does not need to choose a higher level of technology to stop the

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certain situations for a particular player. However, it does not detract from our main point that optimal policy depends crucially on the parameters of the game, which are difficult to observe. We discuss this further in the conclusion.

LE from imitating and both the LE and MNE will make higher profits in their Cournot game.

5.2. Policy 2 – Tax or subsidy on LE imitation efforts

The government choice of an optimal tax or subsidy on LE imitation can be shown to be ambiguous as well. As with patent protection discussed above, we simply sketch out cases where either a tax or subsidy would be optimal. First, it is straightforward to see that a subsidy for LE imitation could increase the LE's profit and thus, increase the host government welfare (LE profit net of subsidy cost). For this discussion, consider modeling a per unit tax or subsidy on the LE's effort.[11] It is then easy to show from the LE's problem, represented by equation (5), that the LE's imitation efforts will be higher for any given MNE technology choice with a subsidy. Realizing this response by the LE, over a certain range of the parameters in the model, the MNE will pick a higher level of technology and both the LE and MNE will realize higher profits. It can be shown that host government welfare will also be higher from this policy.[12] This result is in the spirit of the recommendations by Wang and Blomstrom (1992) for the host government to institute policies to encourage imitation by local firms to increase host government welfare.

However, we can also show in our model a situation where a tax on LE imitation will increase welfare. This case is similar to the case in which complete patent protection may be optimal, as detailed above. To see this, refer to figure 1 again. A tax on LE imitation lowers the LE's imitation efforts for any chosen MNE technology which implies that the MNE's loss

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[11] This makes the additional assumption that the LE's effort is observable and measurable.

[12] As is standard, we assume deadweight losses of administering and distributing tax/subsidy revenues is zero.

function from imitation over the relevant range of technology choices, L_M, shifts down with a tax in figure 1. As discussed above, figure 1 depicts a situation where the LE will not engage in any imitation ultimately. However, a tax on the potential imitation lowers the technology that the MNE must use to stop the LE from imitating and this leads to higher (before-tax) profits for both the LE and MNE. Again, it can be shown that host government welfare can improve in this situation.

5.3. Policy 3 – Tax or subsidy on MNE adaption of technology to local conditions

The final policy we consider is a subsidy or tax on the MNE's costs of adapting the chosen technology to the local conditions. It is easy to show that either subsidization or taxation leads to ambiguous results in this situation. Suppose the MNE's adaption costs function in equation (8) becomes $T(\theta_M, s)$ rather than $T(\theta_M)$, where s represents the host government subsidy and it is assumed that $\partial T/ \partial s > 0$. Using the first-order conditions and Cramer's rule, it is simple to show that $\partial\theta_M^* / \partial s > 0$. Turning to the effect of this on the LE's profit, by the implicit function theorem, we can show from equation (5) that a higher level of MNE technology has an ambiguous effect the LE's profits:

$$\frac{\partial \Pi_L^*}{\partial \theta_M} = -C'\alpha(e)\, q_L^*(.) - \frac{\partial K}{\partial \theta_M} \qquad \textbf{(11)}$$

The higher MNE technology creates a bigger technology gap, and hence, greater benefits to the LE (as represented by the first term on the righthand side of (12)), but also raises the cost of imitation (the second RHS term in (12)). Thus, whether a tax or subsidy on MNE adaption costs will improve welfare depends on parameter values as well.

On a final note, our assumption that both firms export obviously affects welfare versus a situation where some of the firms' production is for domestic consumption in the host country. In the case of domestic consumption, the welfare objective function for the LDC government would include an additional term capturing consumer surplus. Consumer surplus depends on the equilibrium price resulting from the firms' Cournot game in the third stage. In turn, the equilibrium price depends on the level of technology each firm has and its effect on production costs and supply. Introducing consideration of consumer surplus leads to an even richer set of scenarios that may take place and highlights even more that optimal government policy is highly dependent on the parameters of the game. For instance, it is easy to imagine situations where the host country would structure policies to encourage high levels of technology from the MNE for its positive effects on consumer surplus, even if it ultimately leads to lower profits for the LE.

6. Conclusion

This paper has provided perhaps a cautionary message about the type of technology that will be used by MNEs in LDCs and the role of LDC governments to influence that decision. The main message is that a variety of outcomes may occur. This makes it is difficult to know what types of technology and spillovers will accrue to the LDC, much less what optimal government policy should be, without knowing very detailed information about the nature of the game and underlying cost and market conditions. In this paper's model, how the LE's costs of imitation and the MNE's cost of adaptation change with the level of technology directly generates a variety of very different potential outcomes. In particular, the presence of imitation in such a model means a

MNE may either pick a much lower or, *conversely,* a much higher level of technology than in the absence of imitation. In turn, one can show that optimal government policy may be either strong or weak patent protection for the MNE, a tax or subsidy for MNE adaptation costs, and/or a tax or subsidy for imitation efforts, depending on parameter values.

Followers of the strategic trade policy literature should not be surprised by this main message. Numerous papers, most notably Eaton and Grossman (1986), have shown that optimal policy in a game theoretic context is often quite sensitive to the nature of the strategic game. Yet, we feel this is a notable message to make in this context for two important reasons. First, many papers in the technology transfer/spillover literature often draw strong conclusions and policy implications from models that are subject to these criticisms. In other words, reasonable changes in their assumptions can often lead to opposite results and policy conclusions. As has been noted with strategic trade policy, government intervention by LDCs in technology transfer/spillover issues can be a dangerous game. For example, to what extent have MNEs stayed away from LDCs with distortionary policies intended to "benefit" the country from technology transfer/spillovers? The second important reason for this paper is to hopefully guide future research, especially empirical work, toward issues that are relevant for understanding these issues.

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FIGURE 1:
MNE's Optimal Choice of Technology With and Without Imitation

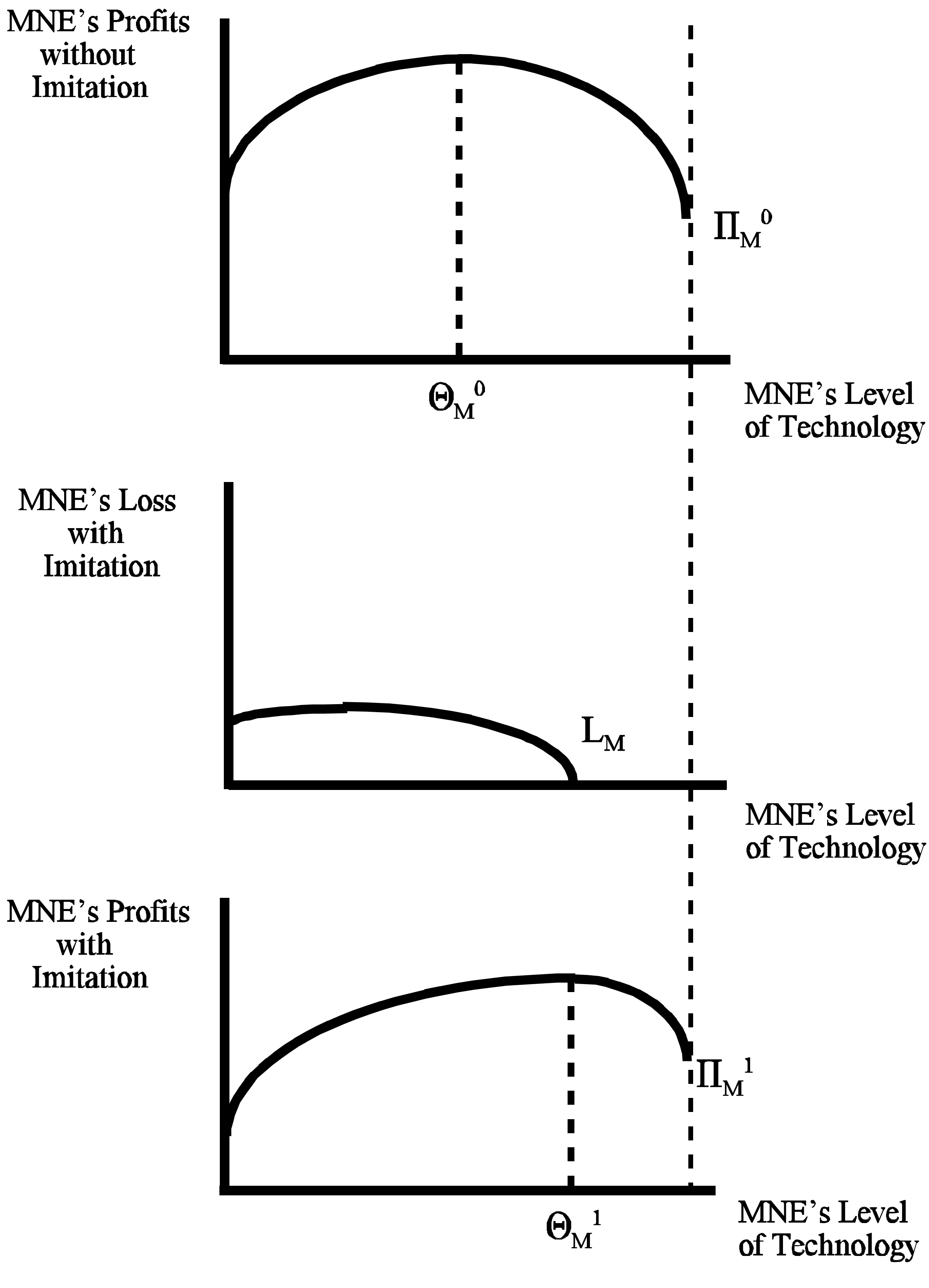

FIGURE 2:
MNE's Optimal Choice of Technology With and Without Imitation