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## Component-based Technology Transfer: Balancing Cost Saving and Imitation Risk

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Technology transfer offers global firms an opportunity to reduce the costs involved in serving emerging markets as well as to source from low-cost locations for their home markets. However, it also poses a potential risk of imitation by local competitors who may enter the market(s). We introduce a component-based technology transfer instrument for the global firm to either deter or accommodate the imitator's entry, by recognizing that components can differ in two dimensions: cost-saving potential and imitation risk. By choosing the range of components to transfer, the global firm's decision has an impact not only on the imitator's fixed entry costs, but also on the post-entry competition based on variable costs. Hence, the proposed instrument leads to two different types of deterrence strategies: "barrier-erecting strategy" and "market-grabbing strategy" by transferring a lower or higher amount, respectively, of component technology than in the case of no imitator. Which deterrence strategy the global firm should employ, depends on the level of imitation risk of transferring the components. Some other interesting and counter-intuitive results arise. For example, transferring less technology when the emerging market potential increases can be optimal. Considering a sourcing opportunity for a home market, a larger home market potential makes the deterrence strategy more attractive when the imitation risk is low, but less attractive when the risk is high.

## 1 Introduction

Emerging economies, such as Brazil, China, India, and Russia, are attractive for untapped markets and an ample supply of cheap labor. To exploit both these opportunities, firms are establishing local operations in these emerging markets. This requires the transfer of technology and know-how from the firm's home base to the emerging economies. However, replicating and transferring technology to emerging countries is not without associated risk. It facilitates imitators' market entry by making it much easier for them to imitate the global firm's product. As a result, by establishing local operations in emerging markets, firms may create their own competitors. Firms have fallen into this trap, or are aware of this possibility. In the latter case, firms, if cautious, can control the amount of technology to transfer and hence reduce the risks of imitation. Successful technology transfer strategies in such cases depend on the appropriate selection of component technologies to transfer: For these choices, it is necessary to recognize the differential impact on variable cost savings, fixed transfer costs and imitation risk of transferring the components. The goal of this paper is to study the economic trade-offs that global firms face in carrying out this balancing act, and the resulting strategy of either accommodation or deterrence that arises.

Firms have recognized the possibility of preventing technology leakage by keeping production of some components/operations at home in industries such as medical equipment, semiconductor, pharmaceuticals, and high-tech electronics (*McKinsey Quarterly* 2004, 2005). The most innovative, and high value-adding technologies or components (e.g., control software in medical equipment, power supply systems in telecom equipment, charge-coupled sensors in cameras, and engines in automobiles) are sometimes withheld from the emerging markets. The physical separation of operations successfully limits the employees' mobility, which is a major channel of technology spread to rivals in these industries (Glass and Saggi 2002, Branstetter et al. 2005, 2007). The risks associated with technology transfer can be high if the reduction of imitation costs due to the increased proximity of local firms to the technologies is significant. The reduction in imitation costs due to the transfer of a product or a component is hereafter referred to as the imitation risk of the product or the component.

Global firms deter or accommodate imitators by employing different transfer strategies. Market potential and imitation risk are the determining factors. Some products have a low risk of imitation because of technology transfer, such as apparel, footware, and consumer electronics. Fewer key technologies are contained in their manufacturing processes or labor skills, but more proprietary information resides in the physical forms of the products, such as shapes, configuration and components' interfaces (Varady et al. 1997). Imitators can copy the products by capturing their physical information using reverse-engineering, no matter where the products are made (Samuelson and Scotchmer 2002). That is to say, separating production geographically will not work well in raising imitators' entry barriers. Hence, the firms face low imitation risk by transferring technology. Luxury goods companies, e.g., Prada and Valentino, consequently produce their exclusive lines completely in developing countries such as Turkey and Eastern Europe, to leverage low labor and material costs (*Wall Street Journal* 2005b). Their manufacturing costs are reduced to roughly the equivalent of their local potential competitors. Because of low market potentials in these low-wage countries, these potential imitators do not enter because of unattractive prospective profits. In addition to serving the local market, these high-end fashion goods firms ship their products to developed countries.

The global firm's strategy can be different if the market potential is large. For instance, leaders in the consumer electronics industry, such as Apple and LG, are integrating fashion elements into their products (*Wall Street Journal* 2008). Their strategy has successfully created a high market demand, but in turn makes their products more easily imitable due to their focus on exterior and other tangible features. In this case, the geographical location of the production is of less consequence for imitation. However, the strong global demand enjoyed by these firms makes the entry of local potential imitators inevitable, e.g., Ainol (*Popular Science* 2007). A large local market potential can accommodate more new entrants no matter how cost-competitive the global firms become by localizing their manufacturing. Often, firms retain in developed countries the manufacturing of complex and key components that require advanced human skills and are difficult to transfer. For example, Apple iPod's display module, diagonal touch screen panels, and video processors are still made in the U.S. or Japan (Linden et al. 2007). The increasing markets despite the presence of local imitators.

In some cases, imitators are forced to replicate the organization of the manufacturing processes. Firms do this by hiring away employees from the source company (Branstetter et al. 2005). General Motors' (GM) technology imitation by Asian local manufacturers is a classic example (Asian Case Research Centre 2005, *Business Week* 2005). Just as hiring employees from other companies is easier when companies are located in the same country, the localization of manufacturing operations also makes imitation easier (Das 1987, Glass and Saggi 2002). Hence, the risks associated with technology transfer are high. To raise an entry barrier, the Israel-based irrigation system firm Netafim keeps the production of some of its complex, high imitation risk components at home, so as to make copying difficult (*Business Week* 2006). This prevents imitation because of the low local demand.

The strategy can be different if the market potential is large, however. For instance, in the automobile industry, emerging economies offer a large pool of cheap supply, but the large potential market makes it hard for auto makers to prevent potential imitators from entering (*McKinsey Quarterly* 2002). Rather than transferring partial manufacturing to these emerging economies, the auto makers General Motors and Volkswagen localize *all* production processes (e.g., Volkswagen Polo and Passat, Chevrolet Aveo, Buick Excelle) in their facilities in China (Boston Consulting Group 2008). Although this does invite imitators, the firms leverage the low material and labor costs to the highest extent. More importantly, these companies not only serve local markets, they also plan to export models built in the emerging economies to their existing markets (*Wall Street*)

Journal 2005a).

Clearly, we observe varying strategies employed by firms to balance imitation risk and cost savings arising from technology transfer. The goal of this paper is to understand the key determinants of such strategies. Therefore, we distill from the above and other examples the role of the following important factors in driving the selection of components to transfer:

Variable Cost Reduction. Not all components in a product have the same cost-saving potential when the operations are transferred to emerging countries. For example, the potential cost savings of automobile components are different: Some have negligible cost savings (e.g., windshield and fuel tank), and others can have a cost savings of over 70 percent (e.g., alternator pulley and compressor valve) by sourcing from China or India (*McKinsey Quarterly* 2004). Labor and material requirements are determining factors of variable cost reduction.

**Costs of Technology Transfer**. First, significant costs are attached to the replication and transfer of technology (Galbraith 1990, von Hippel 1994, Szulanski 1996).<sup>1</sup> Fixed transfer costs can be high compared with the net revenue that can be made from the product, particularly when product life cycles are shortening. Second, previous studies have suggested that the transfer cost of a technology depends on its characteristics, such as its complexity (Simon 1962, Schaefer 1987). The amount and complexity level of the technical know-how required to make components can be very different from one component to another (Banker et al. 1990). Standardized components are readily moveable. However, the technology of making complex components, such as the coil suspension spring in automobiles, can be highly costly and time-consuming to replicate and transfer (Howells 1996, Rivkin 2001, *McKinsey Quarterly* 1995, 2004).

**Costs of Technology Imitation**. Technology imitation is costly.<sup>2</sup> Also, technology transfer and imitation processes go hand-in-hand: The higher the transfer cost of a technology, the higher the imitation risk introduced by transferring the technology. This arises since codifying complex technology for the purpose of replication and transfer can significantly reduce outsiders' efforts to

<sup>&</sup>lt;sup>1</sup>GM had great difficulty in transferring manufacturing practices between divisions (*Business Week* 1992), and IBM had limited success in transferring hardware design processes between units (*The Economist*, 1993). The transfer costs comprise two components: (i) resource costs, and (ii) productivity and know-how loss. Teece (1977) for instance, finds that the transmission and assimilation of un-embedded technical know-how accounts, on average, for 19% of project costs. Chew et al. (1990) find transfer of best practice so difficult that the best plants within a company remain twice as productive as the worst. In addition, the lack of absorptive capacity of recipients, and the presence of cultural differences across nations can significantly impede technology transfer (Kedia and Bhagat 1988, Cohen and Levinthal 1990).

<sup>&</sup>lt;sup>2</sup>Imitators incur high costs when developing the product specifications, constructing prototypes and inventing around or developing a non-infringing imitation (Mansfield et al. 1981, Gallini 1992).

interpret and copy it (Kogut and Zander 1992, Zander and Kogut 1995).<sup>3</sup> Hence, components with different levels of complexity have different levels of imitation risk.

As a result, shifting operations to more cost-effective locations enhances imitation risk. Hence, global firms must balance the need to transfer technology in order to lower production costs with the desire to capture new markets, and the need to prevent critical skills and repertoires unintentionally leaking to other firms. A basic trade-off thus arises when high-cost-saving components have a high imitation risk. Hence, the technology and competitive strategies are intertwined: How much and which component technology to transfer and whether to fend off or to tolerate imitators in the emerging economy must be determined simultaneously. The trade-offs, along with firms' strategic interactions, present critical factors that the global firm must take into account when answering the following set of questions: Which and how much technology to transfer? In the presence of imitators, should one transfer more or less? Will the transfer be more or less if the emerging market potential increases? And when should one accommodate the imitator's entry, and does it pay to serve the home market from the more cost-effective location?

In order to address these questions, we develop a stylized model in the following setting: A global firm owns the technology to make a product and a local firm in an emerging market can access the market only if it imitates the global firm's technology. The firm's strategic interactions are modeled as the sequential stages of transfer of technology by the global firm and potential imitation by a local firm (Das 1987), followed by quantity decisions of the two firms. We first consider a situation in which components are heterogeneous in imitation risk, but homogeneous in cost-saving potential. The risk is reflected in the imitation cost reduction due to local component manufacturing. The model provides interesting insights. For instance, we show that the presence of the imitator can provide an incentive to the global firm sometimes to transfer less, and sometimes to transfer more. This arises since the global firm can deter imitation in two ways: It can either keep entry costs high by transferring a low amount of technology (hereafter referred to as the "barrier-erecting strategy"), or gain a high reduction in its variable cost by transferring a high amount of technology in order to compete aggressively and reduce the imitator's profit gain in the case of its entry (hereafter referred to as the "market-grabbing strategy"). Which strategy is more effective depends upon the relative imitation risk introduced by transferring the product: the former when risk is high, the latter otherwise. In addition, in both cases, transferring less technology when the market potential

<sup>&</sup>lt;sup>3</sup>The underlying phenomena of technology transfer and imitation share similarities, regardless of whether the replication occurs within or across firms' boundaries (Polanyi 1966, Winter 1987, Kogut and Zander 1992). Low-complexity technology is as readily imitated as transferred, while high-complexity technology resists both imitation and transfer (Nelson and Winter 1982, Rivkin 2001).

increases can be optimal. Second, considering a sourcing opportunity for the global firm's home market, a larger home market potential makes the global firm focus more on sourcing for its home market rather than capturing the local market. However, because of different deterrence strategies employed by the global firm in different risk cases, a larger home market potential may make the deterrence strategy more attractive when the imitation risk is low, but less attractive when the risk is high. Finally, the introduction of cost-saving heterogeneity has an impact only on whether the global firm should transfer at the high or the low end: Low-imitation-risk (hereafter referred to as "high-end transfer").

The remainder of this paper is structured as follows. We review related literature in §2. We introduce the model and the game setup in §3. We solve and interpret the global firm's optimal strategy considering that the components are homogeneous in cost-saving potential, but heterogeneous in imitation risk, without the sourcing opportunities in §4. The model is then extended to a case in which the global firm considers sourcing for its home market as well in §5, and is then generalized to a case where the components are also heterogeneous in cost-saving potential in §6. In §7, we conclude with managerial implications, limitations, and directions for future research. In Appendix A, we provide additional analysis: comparative statics, a case in which the emerging market potential is uncertain, and a case in which there are multiple imitators in the emerging market. For brevity, we provide proofs in Appendix B.

## 2 Related Literature

The economics of technology imitation have been studied. The models of a firm endowed with a technology entering a foreign market have focused on comparing the fixed costs incurred by the different alternatives. For example, researchers study which entry mode, such as exporting, FDI, or licensing, to choose in the presence of imitation (e.g., Ethier and Markusen 1996), or what technology level to introduce (e.g., Pepall and Richards 1994, Pepall 1997), or both (e.g., Fosfuri 2000). These decisions have an impact on the imitators' fixed imitation costs. The main conclusion is that the size of the imitation cost determines whether or not an entry-deterrence strategy is preferred by the first mover. The models on incumbents deterring later entrants in the same market include using product quality as an instrument to preempt potential entry (e.g., Hung and Schmitt 1992, Donnenfeld and Weber 1995, Lutz 1997), offering a large product line (e.g., Schmalensee 1978, Brander and Eaton 1984, Bonanno 1987), investing in excess capacity (e.g., Dixit 1980, Maskin 1999), or signaling payoff-relevant information (e.g., Milgrom and Roberts 1982), among others. Entry deterrence is achieved

by either raising entrants' entry costs, or reducing their competition payoffs. In addition, all the research to date examines firms' strategic interaction at the product level. From our observations, component-based transfer is another useful "strategic" instrument. This new instrument has an impact on both the fixed imitation cost and firms' post-entry competition based on variable costs, which jointly determine the deterrence strategy. Prior entry-deterrence models also assume that knowledge replication is straightforward and costless (Nelson and Winter 1982). The problem of replication is hence foreign, and imitation and replication are unconnected.

Technology imitation is also studied in the strategic management literature, but technology is differentiated in only one dimension: complexity. Technology replication is an effective strategy to capture new market opportunities (Winter and Szulanski 2001). Technology transfer and imitation share similarities, and high-complexity technology resists both imitation and transfer (Polanyi 1966, Nelson and Winter 1982). Hence, a paradox faced by these firms is identified: Efforts by a firm to replicate its technology enhance the potential for imitation (Kogut and Zander 1992). This literature stream provides a useful framework for our problem: A firm that replicates and transfers technology must factor in the consequences of imitation, and transferring complex technology presents both a high transfer cost as well as a high imitation risk. In this literature, replication and imitation are connected, but the decision of the rival to imitate knowledge is usually exogenously given (e.g., Rivkin 2000, Rivkin 2001). In our work, we endogenize that decision by incorporating both the fixed entry costs and the firms' market competition after entry. In addition, considering that access to favorable production factors is a main purpose of technology transfer, we differentiate technology in two dimensions: imitation risk and cost-saving potential.

In the operations management literature, researchers study manufacturing strategies and material flow in a multiple-country setting. The focus has been on the factor-cost differences and untapped markets as drivers of global manufacturing. For example, Kogut (1985) qualitatively describes the design of component manufacturing strategies to capitalize on the comparative advantage of countries, and Shi and Gregory (1998) identify several key benefits of geographically dispersed manufacturing networks, which include penetrating into new markets and access to favorable production factors. However, in these models, technology can be duplicated at no cost, and imitation aspects have remained largely unexplored. Researchers study the organization of global manufacturing networks by minimizing the total production and transportation costs. For example, Flaherty (1986) conceptually derives a multi-plant configuration in terms of material flows, and Cohen and Lee (1989) develop a mathematical programming model to analyze deployment of resources in a global manufacturing and distribution network. In these models, the demand side is assumed to be fixed and irrelevant. One goal of our work is to study how the market potentials play a role in a firm's decision to arrange its manufacturing network, by incorporating fixed configuration costs, and market competition. Relevant work in the literature on international technology diffusion is reviewed well in Keller (2004), and international operations management in Roth et al. (1997) and Prasad and Babbar (2000). China, as a prime target for direct foreign investment as well as a major player in global manufacturing, is emerging as a uniquely interesting location for research. Opportunities and challenges for China-based research are discussed by Zhao et al. (2006, 2007), highlighting issues such as logistics, supply chain management, quality management, and new product development. Despite the relevance of potential imitation as a consequence of technology diffusion, no research to date has studied how these factors are linked.

## 3 The Model

We introduce our assumptions concerning the firms, products, technology, market demand, decision set, and cost structures in §3.1. The game setup and equilibrium conditions are described in §3.2.

#### 3.1 Model Setup

Players, markets and products: We consider two firms: A "global" firm with its current operations in a "home" country, and a "local" imitator in a foreign country with an emerging economy. The global firm has developed in the home country a set of "component technologies." Each component technology delivers a component, and all components are then assembled into a final product. For expositional purposes, we consider first in §4 only one market for the final product, the emerging market. In §5, we consider two markets for the final product: The emerging economy and a market in the home country. The global firm has no operations in the emerging economy before any component technology is transferred. The global firm considers entering the market of the emerging economy. In the emerging economy, there is one local firm that has no component technology to manufacture the product (Considering n local firms does not substantially change our insights, as discussed in Appendix B). To enter the emerging market, the local firm has to first imitate *all* component technologies, either from the local operations or from the home operations of the global firm.

**Demand:** We assume that the demand function is linear in the emerging market, with a total demand potential  $\xi$ . In the case of a monopolist, the market is cleared at price  $p = \xi - q$ , if the monopolist sets an output level q. In the case of a duopoly, the market-clearing price is given by

 $p = \xi - q^G - q^L$ , if the two firms set output levels at  $q^G$  and  $q^L$ , respectively. We assume that  $\xi$  is common knowledge to all players.

Component technology and associated costs: We assume that the set of components that makes up the product forms a continuum with a total volume that is normalized to 1. We label these components from 0 to 1. The global firm can decide where to produce components (either in the home country or in the emerging country). In the case that it decides that some production of components occurs in the emerging market, "component technology transfer" (or, in short, technology transfer) is required before local production can take place. The global firm transports the components made by its home operations to its local operations and assembles the final product with the locally made components for its demand in the local market. Each component may have a different variable cost-saving potential if it is transferred to the emerging economy. The variable cost of the final product is then the sum of the variable cost of each component, a function of where components are produced. The transfer cost of each component may also be different. Transferring complex technology presents a high transfer cost. The total fixed transfer cost is, then, the sum of the transfer cost of each component that has been transferred. To make the analysis insightful, in a base model, we first assume that all components have identical cost-saving potential; however, we allow the transfer costs of components to differ. In §6, we allow components to differ both in variable cost-saving potential and transfer costs.

The global firm's production costs: The variable cost of manufacturing the product in the home country is c > 0, and is normalized to 0 in the emerging country. Assuming that a fraction x of the components is transferred to the emerging economy, the global firm's variable cost has two components: The production cost of x fraction components transferred, and the production cost of the rest (1 - x) fraction components remaining in its home operations. For the sake of simplicity, we suppress the costs of shipping components between the two markets. As all components are homogeneous in variable cost-saving potential in the base model, the variable cost after transferring x fraction becomes:

$$c(x) = c(1-x).$$
 (1)

When all manufacturing remains at home, i.e., x = 0, the global firm's variable cost is given by c(0) = c. When all components are transferred, i.e., x = 1, the global firm's variable cost is c(1) = 0.

The global firm's transfer costs: Transferring technology is costly. The costs depend on the amount of technology transferred x, denoted by  $K^{G}(x)$ . The more technology the firm transfers, the higher are the fixed costs, i.e.,  $\frac{d}{dx}K^{G}(x) > 0$ . The firm incurs no transfer cost if there is no transfer,

i.e.,  $K^G(0) = 0$ . When there is full transfer, the total transfer cost is denoted by  $K^G(1) = k^G$ . Recall that we allow components to have different transfer costs. Hence,  $K^G(x)$  is a non-linear function of x. In order to capture the heterogeneity, we model the impact of the transfer decision on the global firm's transfer cost using an "impact function"  $F(x;\gamma) \in [0,1]$ , where  $\gamma \ge 0$  measures the components' heterogeneity in transfer costs. The total transfer cost of x fraction components is given by:

$$K^{G}(x) = k^{G}F(x;\gamma).$$
<sup>(2)</sup>

 $\gamma = 0$  represents homogeneous transfer costs. The transfer cost is then linear in x:  $K^G(x) = k^G x$ .  $\gamma > 0$  represents higher difference in transfer costs among components. The impact function satisfies condition  $\frac{\partial}{\partial x}F(x;\gamma) > 0$ , i.e., the transfer cost is higher when more technology is transferred. We assume that the firm first transfers the components with the lowest transfer costs, hence,  $\frac{\partial^2}{\partial x^2}F(x;\gamma) > 0$ , i.e., the transfer cost of the marginal component x is increasing. We also specify a functional form of  $F(x;\gamma)$  discussed later.

The local firm's production costs: The local firm's variable cost is normalized to zero. Hence, the global firm has a cost disadvantage of c when not transferring any technology, and this becomes at par with the local firm when transferring all technology.

The local firm's imitation costs: In order to capture how the location of the operations impacts the imitator's behavior, we assume that the imitation costs are lower when more technology is local. In order to imitate the technology for making the product, the imitator undertakes an investment. If no technology is transferred, the imitator incurs  $k^L$  costs to imitate *all* technology from the global firm's home operations. The parameter,  $k^L$ , hence captures the imitator's imitation capability.<sup>4</sup> A lower  $k^L$  means a higher imitation capability. Transferring all components to the emerging country lowers the imitation costs by a percentage  $\alpha \in [0, 1]$ . We refer to  $\alpha$  as the "imitation risk" of transferring the product. In our model, this is an important parameter as it captures how sensitive the entrant's imitation costs are with respect to technology transfer. It allows us to determine the imitator's fixed imitation cost as a function of the global firm's transfer decision x. Imitation and transfer are thus related processes. The higher the transfer cost of a component technology, the higher is the reduction of imitation cost resulting from transfer of the component. The imitation

<sup>&</sup>lt;sup>4</sup>Spillovers of technology to imitators are possible only if they possess sufficient "absorptive capacity" (Cohen and Levinthal 1990). Limited absorptive capacity can possibly arise from lack of prior related technology, or lack of template (Rivkin 2001). This determines the imitator's efforts  $k^L$  to invest in order to replicate technology from the global firm. Would-be copycats must rely on search heuristics or on learning, not on algorithmic "solutions," to match the performance of superior firms (Rivkin 2000). Empirical work by Levin et al. (1987) quantitatively studies such deterrence to imitation.

cost reduction due to the transfer of the component technology reflects the imitation risk of the component. Therefore, we assume that the imitation cost reduction,  $[k^L - K^L(x)]$ , follows a similar shape to that of the technology transfer:  $\alpha k^L F(x; \gamma)$ . The imitation cost, given that x fraction components are transferred, is then given by:

$$K^{L}(x) = k^{L} \left[ 1 - \alpha F(x;\gamma) \right], \tag{3}$$

where the impact function  $F(x; \gamma)$  is the same as in the transfer cost (2). Transferring x fraction components lowers imitation costs by a fraction  $\alpha F(x; \gamma)$ .

**Impact function:** We impose the following properties on the impact function F:

1. Both the transfer cost and imitation cost reduction are zero when there is no transfer, and highest when there is full transfer, i.e.,  $F(0; \gamma) = 0$ , and  $F(1; \gamma) = 1$ .

2. Both the transfer cost and imitation cost reduction increase with the transfer amount x, i.e.,  $\frac{\partial}{\partial x}F(x;\gamma) > 0$ , and the marginal transfer cost and imitation cost reduction increase with x, i.e.,  $\frac{\partial^2}{\partial x^2}F(x;\gamma) > 0$ .

3. Both the transfer cost and imitation cost reduction linearly increase with the transfer amount x if components are homogeneous, i.e., F(x; 0) = x.

4. Both the transfer cost and imitation cost reduction decrease with the heterogeneity  $\gamma$ , i.e.,  $\frac{\partial}{\partial \gamma}F(x;\gamma) < 0$ . Figure 1 illustrates  $F(x;\gamma)$  for different values of  $\gamma$ . Notice that, as  $\gamma$  increases, the convexity of F increases, capturing the fact that there is more heterogeneity in fixed transfer costs. For the sake of simplicity, we consider the following quadratic function that satisfies the properties above<sup>5</sup>:

$$F(x;\gamma) = \frac{x(1+\gamma x)}{1+\gamma}.$$
(4)

This function is simple and depends on only one parameter that captures the heterogeneity  $\gamma$ . We use it to model our cost structure.

#### 3.2 Game Setup

Now we discuss the structure of the game played by the global firm and the imitator.

**The decisions:** The decisions by the global firm and the imitator relating to transfer, imitation and manufacturing are the following:

<sup>&</sup>lt;sup>5</sup>In fact,  $F(x;\gamma)$  is the integral of a linear function over the component space:  $F(x;\gamma) = \int_0^x \frac{1+2\gamma\theta}{\gamma+1} d\theta$ . Namely, we assume that the transfer cost or the imitation risk of component t is linearly increasing in  $t \in [0,1]$ . We have a normalization term  $\frac{1}{1+\gamma}$  because the total transfer cost or imitation cost reduction by transferring all components, x = 1, has to be fixed, i.e.,  $F(1;\gamma) = 1$ .



Figure 1: Impact function  $F(x; \gamma)$  for values of heterogeneity  $\gamma = 0, 1$  and 20.

<u>Global firm</u> The global firm's decisions include: (i) the amount of components to transfer to the emerging market, characterized by  $x \in [0, 1]$ ; and (ii) an output level,  $q^G \in [0, \xi]$ .

<u>Imitator</u> The imitator can potentially enter by imitating the transferred technology from the global firm's local operations, and the rest from its home operations. The imitator's decisions are (i) whether to enter, denoted by y = 0 or 1 ('0' denotes no entry, '1' denotes entry); and (ii) an output level:  $q^{L} \in [0, \xi]$ .

The game: We model the decisions of the two firms as a sequential process and consider three stages: Technology transfer, imitation, followed by a quantity (Cournot) competition. The global firm is a Stackelberg leader, and the local imitator is a follower. Each player has perfect information about its rival and the demand. In <u>Stage I</u>, the global firm decides what fraction of the components to transfer,  $x \in [0, 1]$ . In <u>Stage II</u>, after observing x, the potential imitator decides whether to enter,  $y \in \{0, 1\}$ . In <u>Stage III</u>, firms observed each other's decision, and either the global firm behaves as a monopolist and sets an output level  $q(x) \in [0, +\infty)$ , or, if the prospective imitator enters, the two firms enter a quantity competition by setting output levels,  $q^G(x) \in [0, +\infty)$  and  $q^L(x) \in [0, +\infty)$ respectively, contingent on the transfer x.

The firms' corresponding Stage III profits are then:

$$\pi^{G}(x,y) = \begin{cases} \pi^{M}(q(x);x) & y = 0\\ \pi^{G}(q^{G}(x),q^{L}(x);x) & y = 1 \end{cases},$$
(5)

and

$$\pi^{L}(x,y) = \begin{cases} 0 & y = 0 \\ \pi^{L}\left(q^{L}(x), q^{G}(x); x\right) & y = 1 \end{cases},$$
(6)

where  $\pi^{M}(q; x)$  is the global firm's monopoly profit for a given quantity q, and a technology transfer decision x, and  $\pi^{i}(q^{i}, q^{-i}; x)$  is firm *i*'s duopoly profit for a given its own quantity  $q^{i}$ , its competitor's quantity  $q^{-i}$ , and a technology transfer decision x. Both exclude fixed costs. We hereafter refer to the Stage III profit  $\pi^{i}(x, y)$  as "emerging market profit" of firm  $i \in \{G, L\}$  after entering the emerging market.

The imitator's best response  $y^{*}(x)$  at Stage II is then given by:

$$y^{*}(x) \in \underset{y \in \{0,1\}}{\operatorname{arg\,max}} \Pi^{L}(x,y)$$

and the global firm's sub-game perfect equilibrium strategy  $x^*$  at Stage I is given by:

$$x^* \in \underset{x \in [0,1]}{\operatorname{arg\,max}} \Pi^G \left( x, y^* \left( x \right) \right)$$

where,

$$\Pi^{i}(x,y) = \pi^{i}(x,y) - K^{i}(x)$$
(7)

is referred to as "net profit" of firm  $i \in \{G, L\}$ , i.e., the emerging market profit  $\pi^i$  net the fixed entry cost  $K^i$ .

The equilibrium analysis of the model provides insights into how the global firm's technology transfer decision depends on the imitator's strategic reaction and technology, market, and cost structures. If the imitator chooses to enter, it competes for a share in the emerging market. Confronting this imitator, the global firm needs to assess deterrence (the firm is a monopoly), or accommodation (the firm and the competitor co-exist in the market) strategies by controlling the amount of components to transfer. We summarize the notations in Table 1.

### 4 Model Analysis

In this section, we analyze the equilibrium outcome of the base model. In the first subsection  $\S4.1$ , we explain some useful preliminary results. In the following subsection  $\S4.2$ , we study the equilibrium strategies of the two firms: global and local. We then qualitatively interpret our results using some examples in subsection  $\S4.3$ .

#### 4.1 Preliminary Results

The global firm determines the optimal transfer amount of components,  $x^m$  or  $x^d$ , when it is a monopolist or duopolist, respectively, by trading off variable cost-reduction benefits with fixed transfer costs, i.e.,  $x^m = \underset{x \in [0,1]}{\arg \max} \Pi^G(x, 0)$ , and  $x^d = \underset{x \in [0,1]}{\arg \max} \Pi^G(x, 1)$ . We now discuss a key property of the optimal technology transfer decision:

**Proposition 1** (1) The firm makes a higher profit by transferring more components in both monopoly and duopoly markets  $x^m$  and  $x^d$  when the market potential  $\xi$  increases.

(2) The firm transfers more components as a monopolist than a duopolist, i.e.,  $x^m \ge x^d$ .

Parameters	Meanings		
$K^i$	Fixed cost of firm $i \in \{G, L\}$		
С	Variable cost of the global firm in the home country		
F	Impact function of transfer decision $x$ on variable and fixed costs		
$\gamma$	Component heterogeneity		
α	Imitation risk of the product		
$k^L$	Cost to imitate all technology from the home market		
$x^m$	Monopoly optimal (or base) transfer amount		
$x^d$	Duopoly optimal transfer amount		
$x^l, x^h$	Boundaries of no-entry region $x^l \leq x^h$		
Decision variables			
x	Global firm's transfer amount decision $x \in [0, 1]$		
y	Imitator's entry decision $y \in \{0, 1\}$		
$q^i$	Production quantity of firm $i$		
Payoffs			
$\Pi^i$	Net profit of firm <i>i</i>		
$\pi^i$	Emerging market profit of firm $i$		
Derived parameters			
$\hat{\alpha}$	Critical imitation risk		
<u>ξ</u>	Market potential below which $x^m$ deters entry		
$\overline{\xi}$	Market potential below which the global firm prefers deterrence		
$\widehat{\xi}$	Market potential above which the global firm cannot deter		

Table 1. Summary of the notations used in the paper.

It follows from Proposition 1 that, when facing a larger market potential, the fixed transfer cost concern becomes less important, and the firm benefits more from variable cost reduction. In the presence of a competitor, the global firm receives a lower marginal profit increase from the variable cost reduction while the fixed transfer costs remain the same, which results in less transfer than in the monopoly case. In the remainder of the paper, we refer to  $x^m$  as the "base" technology transfer amount, i.e., the amount that the monopolist would transfer, ignoring competitive effects. We will analyze cases when the equilibrium technology transfer amount is higher or lower than the base technology transfer amount.

#### 4.2 Technology Transfer in the Presence of an Imitator

We now study the situation in which a potential imitator can enter the emerging market by imitating the global firm's technology. A Stage III subgame equilibrium analysis is given in Lemma 2 in Appendix B. In the following subsection, we first analyze the imitator's best response in Stage II to a given transfer decision x of the global firm. We then analyze the global firm's best strategy in Stage I. Finally, we study how the presence of the imitator impacts the global firm's optimal transfer decision  $x^*$ .

#### 4.2.1 Imitator's Best Response

Assume that the global firm has transferred a fraction x of the components to the local market. The imitator enters only when the projected profits exceed the entry cost, i.e.,

$$y^{*}(x) = \begin{cases} 1 & \text{if } \Pi^{L}(x,1) > 0 \\ 0 & \text{o/w} \end{cases}$$

We now study a useful property of the local firm's profit in the case that it enters.

**Lemma 1** The imitator's net profit,  $\Pi^{L}(x, 1)$ , in the case of entry is convex in the transfer amount, x.

The imitator's net profit is convex in the transfer amount x because its emerging market profit  $\pi^L$  is convex, while its imitation cost  $K^L$  is concave in x. The concavity of the imitation cost, or the convexity of the imitation cost reduction  $\alpha k^{L}F(x;\gamma)$ , is due to the increasing imitation cost reduction of transferring the marginal component x. That the imitator's emerging market profit  $\pi^{L}$  is decreasing, but at a decreasing rate, in the transfer amount x or the global firm's variable cost reduction, stems from the downward sloping demand function (see Lemma 2 in Appendix B). An important consequence of the convexity of the imitator's net profit is that the global firm can influence the competitive landscape by controlling the amount of technology transfer. Entry is not attractive for the local firm when the global firm transfers neither too much technology nor too little. We denote  $[x^l, x^h]$  as the no-entry region. The boundaries,  $x^l$  and  $x^h$ , are both a function of market potential  $\xi$  and determined by:  $\Pi^{L}(x,1) = 0$ . It can be shown that the net profit  $\Pi^{L}(x,1)$ increases with the market potential  $\xi$ . Hence, there exists a minimum market potential  $\hat{\xi}$ , such that for any market potential above this critical level,  $\xi > \hat{\xi}$ , the imitator obtains positive profit for any possible transfer amount x. In other words, at the critical potential,  $\hat{\xi}$ , the no-entry region  $[x^l, x^h]$ shrinks to a single point, i.e.,  $\hat{x} \doteq x^l = x^h$ , and, for larger potentials, the no-entry region becomes empty. This is summarized in the following proposition:

**Proposition 2** There exists a critical market potential  $\hat{\xi}$ , such that the imitator's best response is as follows:

(1) If the market potential is below the critical potential,  $\xi \leq \hat{\xi}$ :

The imitator enters, i.e.,  $y^*(x) = 1$ , when the global firm transfers a low amount  $x \in [0, x^l)$  or a high amount,  $x \in (x^h, 1]$ . The imitator does not enter, i.e.,  $y^*(x) = 0$ , when the global firm transfers a medium amount,  $x \in [x^l, x^h]$ .

(2) Otherwise: The imitator always enters, i.e.,  $y^*(x) = 1$ , for any transfer amount  $x \in [0, 1]$ .

In addition, the no-entry region shrinks as the market potential increases, i.e.,  $\frac{\partial x^l}{\partial \xi} > 0$ , and  $\frac{\partial x^h}{\partial \xi} < 0$ for  $\xi \leq \hat{\xi}$ .

Proposition 2 underlines the importance of the market potential. For large markets, i.e.,  $\xi > \hat{\xi}$ , the global firm cannot prevent entry with a controlled transfer of technology. When the market potential is not large, i.e.,  $\xi \leq \hat{\xi}$ , the imitator enters when it reaps a high emerging market profit,  $\pi^L$ , or incurs a low entry cost,  $K^L$ , such that the net profit,  $\Pi^L(x, 1)$ , becomes positive. The former happens when the global firm transfers a low amount  $(x \in [0, x^l))$ , such that the imitator faces a weak competitor who has a strong cost disadvantage to the imitator. The latter happens when the global firm transfers a high amount  $(x \in (x^h, 1])$ , such that the imitator incurs low imitation costs due to the presence of a large amount of components at the global firm's local operations. Finally, the no-entry region shrinks as the market potential increases since the imitator's entry becomes easier due to a higher potential emerging market profit after entry, i.e.,  $\frac{\partial x^l}{\partial \xi} > 0$  and  $\frac{\partial x^h}{\partial \xi} < 0$ .

#### 4.2.2 Global Firm's Technology Transfer Decision: Generic Insights

The imitator's best response in Proposition 2 indicates that the global firm can use technology transfer as a tool to deter imitation. The medium region,  $x \in [x^l, x^h]$ , if it exists, is a region that guarantees the imitator's no entry. If the base technology transfer amount,  $x^m$ , falls in this region, the global firm reaps the highest profits as well as deters the imitator's entry. It is possible that the base transfer amount,  $x^m$ , does not fall in this no-entry or deterrence region. In other words, if the global firm wants to deter a potential imitator, it has to forego some benefits in variable cost reduction (low transfer costs) by transferring a lower (higher) amount of components than the base transfer amount. This aspect is stated in the following proposition:

**Proposition 3** There exists a critical imitation risk  $\hat{\alpha}$ , and a critical market potential  $\underline{\xi}$ , such that, (1) Under low risk  $\alpha < \hat{\alpha}$ :

$$\begin{cases} x^m \in \begin{bmatrix} x^l, x^h \end{bmatrix} & \text{for } 0 < \xi \le \underline{\xi} \\ x^m \in \begin{bmatrix} 0, x^l \end{pmatrix} & \text{for } \underline{\xi} < \xi < \widehat{\xi} \end{cases}$$

(2) Under high risk  $\alpha \geq \hat{\alpha}$ :

$$\begin{cases} x^m \in \begin{bmatrix} x^l, x^h \end{bmatrix} & \text{for } 0 < \xi \le \underline{\xi} \\ x^m \in \begin{bmatrix} x^h, 1 \end{bmatrix} & \text{for } \underline{\xi} < \xi < \widehat{\xi} \end{cases}$$

Proposition 3 explains how the imitation risk plays a key role in determining whether the optimal monopoly transfer amount,  $x^m$ , lies inside, below, or above the no-entry region  $[x^l, x^h]$ . When the market potential is low, the base transfer amount,  $x^m$ , lies inside the no-entry region, irrespective of the imitation risk. In other words, the base transfer amount deters a potential entrant. In these situations, a global firm can safely transfer technology to an emerging economy by trading off the variable cost savings against the incurred fixed costs, ignoring any competitive interaction. However, when the market potential is high, if the global firm transferred the base transfer amount, it would attract an imitator and, hence, the Stage III competition equilibrium would be a duopoly. In order to ensure that it remains a monopolist in Stage III, the global firm must transfer more than the base transfer amount in the case of low imitation risk, in order to be in the no-entry region. This is captured in statement (1) in Proposition 3. Interestingly, with a high imitation risk, the situation is different. For high market potentials, the global firm needs to transfer less than the base transfer amount in order to prevent the imitator's entry. This is stated in statement (2). The difference in behavior between Proposition 3(1) and 3(2) illustrates the key role that the imitation risk,  $\alpha$ , plays. The intuition is as follows: With low imitation risk, the location of the operations does not greatly influence the imitator's fixed entry costs. Hence, the only way to make entry unattractive is to make the imitator's emerging market profit after entry low. This can be done through a fierce cost competition, i.e., by transferring a high amount of components and making the global firm's variable cost very low. We refer to this as the "market-grabbing strategy". This strategy does not work with a high imitation risk, in which case it would reduce the imitator's fixed cost and open the prospect of entry. With a high imitation risk, the strategy, then, is to create a high entry barrier by transferring less than the base transfer amount, such that the imitator has to face high fixed entry costs. We refer to this as the "barrier-erecting strategy."

Consider now the strategic behavior of the global firm at its technology transfer stage. Proposition 3 suggests that the global firm has two ways to deter the imitator's entry – by intentionally transferring either more or less than the base transfer amount. Both deterrence strategies come with associated costs: In the former, the firm foregoes some cost-saving benefits; in the latter, the firm incurs high transfer costs. Therefore, when the global firm has an option to deter, i.e., the no-entry region  $[x^l, x^h]$  is non-empty, it may want to forego the deterrence option, and instead accommodate the imitator's entry if it gains higher duopoly profits. We now introduce another critical market



Figure 2: Optimal competitive strategy regions defined by critical market potentials  $\underline{\xi}, \overline{\xi}$ , and  $\hat{\xi}$  (for  $\overline{\xi} < \hat{\xi}$ ).

potential,  $\overline{\xi}$ , below which the global firm always wants to deter the imitator's entry. In this case, we must restrict the range of market potential to  $[0, \widehat{\xi}]$ , in which the global firm can effectively deter entry (otherwise, the no-entry region,  $[x^l, x^h]$  is empty, see Proposition 2).  $\overline{\xi}$  is determined as follows:

$$\overline{\xi} = \begin{cases} \widehat{\xi}, & \text{if } \Pi^G\left(\widehat{x}, 0\right) \ge \Pi^G\left(\widehat{x}^d, 1\right) \\ \xi : \Pi^G\left(x^d, 1\right) = \max_{x \in [x^l, x^h]} \Pi^G\left(x, 0\right), & \text{otherwise} \end{cases},$$
(8)

where  $\hat{x}^d$  is the duopoly optimal transfer amount at  $\xi = \hat{\xi}$ . The critical market potentials,  $\underline{\xi}$ (Proposition 3),  $\overline{\xi}$ , and  $\hat{\xi}$  (Proposition 2), are summarized in Figure 2.  $\overline{\xi}$  can be interpreted as follows: When at the highest possible market potential ( $\hat{\xi}$ ) below which the entrant can be deterred, more profits are made from deterring entry by transferring  $\hat{x}$  than accommodating; then, for all lower market potentials, the global firm prefers deterring. If that is not the case, then there exists a market potential below which the firm prefers to deter, and above which the firm prefers to accommodate. The firm prefers to accommodate the entrant, even though it would have been able to deter, because the costs of deterrence are too high compared with the benefits. Because the no-entry region becomes empty for any market potential above  $\hat{\xi}$  (Proposition 2), it is immediate that  $\overline{\xi} \leq \hat{\xi}$ .

Recall from Proposition 3 that the imitation risk plays a critical role in the deterrence capabilities of the global firm. Therefore, we discuss separately the equilibrium technology transfer decision when the imitation risk is high vs. when it is low.

#### 4.2.3 Global Firm's Technology Transfer Decision when the Imitation Risk is High

Recall that a high imitation risk ( $\alpha \geq \hat{\alpha}$ ) implies that the imitation costs do decrease significantly as a function of the technology transferred to the emerging market (i.e.,  $k^L$  if no technology is transferred vs.  $k^L (1 - \alpha)$  if all technology is transferred). In that case, we obtain:

#### **Proposition 4** For high imitation risk $\alpha \geq \hat{\alpha}$ ,

(1) If the market potential is low ξ ≤ ξ, the global firm employs a "barrier-erecting strategy" to deter the imitator's entry by transferring no more than the monopoly optimal amount: x\* = min [x<sup>m</sup>, x<sup>h</sup>];
(2) If the market potential is high ξ > ξ, it accommodates by transferring the duopoly optimal amount: x\* = x<sup>d</sup>.

Proposition 4 reveals the important interplay between market potential and transfer strategy when the imitation risk is low. For low market potentials, the global firm can transfer as if it were a monopolist. As the market potential increases, the global firm is likely to invite an entrant if it were to continue to transfer the base amount,  $x^m$ . The global firm transfers less technology,  $x^h$ , than the base amount in order to deter the entrant. The monopolist essentially erects a barrier for the potential entrant by making it more difficult for the imitator to enter the market. The global firm loses variable cost-competitiveness in the emerging market because less than the (monopoly) optimal amount of technology is transferred. Based on our conversations with executives at Mine Safety Appliances Co. (MSA), a world-leading company in safety equipment, in the context of technology transfer to Asia of microbolometer thermal detectors (sensors) and other electric components in thermalimaging cameras, this strategy has been followed. Global companies thus knowingly keep some key technologies at home in order to make imitation difficult.<sup>6</sup> When the market potential increases to a level,  $\overline{\xi}$ , such that the determine strategy becomes less attractive because of the cost-saving benefits forgone, the global firm foregoes the deterrence option and accommodates the imitator. This situation was experienced by General Electric (GE) in the context of transfer of locomotive technology to China. Due to the high market potential of the Chinese locomotive market, GE knew that local firms were likely to enter the market. By transferring most of its technology to China and lowering its variable cost, GE sought gains in market share (as well as the ability to source parts back to the existing markets).<sup>7</sup> The accommodation was accompanied by an upward jump in the technology transfer amount (from  $x^h$  to  $x^d$ ).

#### 4.2.4 Global Firm's Technology Transfer Decision when the Imitation Risk is Low

In the case of low risk,  $\alpha < \hat{\alpha}$ , the imitation costs are not significantly impacted by the transfer amount. In that case, we obtain:

<sup>&</sup>lt;sup>6</sup>This is based upon a pilot study carried out at MSA's plants in the US and Asia, and conversations with Vice President of Operations Mr. Uhler, and regional operations executives Mr. Digiovanni, and Mr. Hsu., when the first author was serving on their Global Manufacturing Council from 2004 to 2005.

<sup>&</sup>lt;sup>7</sup>This is based upon our conversations with President of GE MONEY, Mr. Fujimore, on March 8th, 2007.

#### **Proposition 5** For low imitation risk $\alpha < \hat{\alpha}$ ,

(1) If the market potential is low ξ ≤ ξ, the global firm employs a "market-grabbing strategy" to deter the imitator's entry by transferring no less than the monopoly optimal amount: x\* = max [x<sup>m</sup>, x<sup>l</sup>];
(2) If the market potential is high ξ > ξ, the global firm accommodates by transferring the duopoly amount: x\* = x<sup>d</sup>.

Interestingly, the interplay between the market potential and technology transfer strategy becomes more subtle. When the market potential is low, the global firm can again ignore any competitive effect and simply transfer the base amount that is optimal for a monopolist in the emerging market. When the market potential increases, the transfer amount increases (Proposition 1), but, at the same time, the imitator will more likely enter if the global firm continues to transfer the base amount. Contrary to the high imitation risk case, this entry threat forces the global firm to transfer more,  $x^{l}$ , than the base amount, above a certain market potential, in order to deter the entrant. The reason for this increase in transfer is that transferring technology does not create significant imitation risk and hence, reducing the potential imitator's emerging market profits by producing products at a very low cost is the alternative. This is an interesting, and perhaps less intuitive, strategy. The global firm incurs high transfer costs, but gains variable cost-competitiveness in the emerging market because more than the base amount of technology is transferred. When the market potential increases to a level,  $\overline{\xi}$ , such that the determine strategy becomes less attractive because of the high transfer costs, and the global firm foregoes the deterrence option and accommodates the imitator. The accommodation is accompanied by a drop in the technology transfer amount (from  $x^l$  to  $x^d$ ).

#### 4.2.5 Comparative Statics

Now, we can combine the above results and discuss how the global firm's optimal technology transfer amount  $x^*$  changes as a function of the market potential.

**Corollary 1** (1) When  $\alpha < \hat{\alpha}$ , as  $\xi$  increases, the technology transfer  $x^*$  is determined by  $x^m$ ,  $x^l$ and  $x^d$ , with respectively,  $\frac{\partial x^m}{\partial \xi} \ge 0$ ,  $\frac{\partial x^l}{\partial \xi} \ge 0$ ,  $x^m < x^l$ , and  $x^l > x^d$ ; (2) When  $\alpha \ge \hat{\alpha}$ , as  $\xi$  increases, the technology transfer  $x^*$  is determined by  $x^m$ ,  $x^h$  and  $x^d$ , with respectively,  $\frac{\partial x^m}{\partial \xi} \ge 0$ ,  $\frac{\partial x^h}{\partial \xi} < 0$ ,  $\frac{\partial x^d}{\partial \xi} \ge 0$ ,  $x^m > x^h$ , and  $x^h < x^d$  for higher risk  $\alpha \ge \hat{\alpha}' (> \hat{\alpha})$ ,  $x^h \ge x^d$  otherwise.

Corollary 1 summarizes how the optimal transfer strategy changes as a function of market potential. It is interesting to note that the change is not monotone: When the imitation risk is low, more technology is transferred as market potential increases. This is intuitive because the marginal revenues of transferring technology increase while the marginal costs are unaffected by the market potential. When the market potential becomes high, the global firm has to deploy its technology transfer strategy to keep out the entrant by transferring more technology,  $x^l$ , than the base amount,  $x^m$ . It allows the firm to become cost competitive. Only when the global firm loses too much by trying to keep the entrant out of the market, does the global firm scale back the technology transfer amount from  $x^l$  to  $x^d$ . This reason for this change is that the revenues from the emerging market now have to be shared with the new entrant. As a result, the marginal returns of the transfer decrease (discontinuously).

When the imitation risk is high, it becomes less intuitive to determine how the market potential impacts the technology transfer strategy: Only when the market potential is low, more technology is transferred as market potential increases (for the same intuitive reason as above). However, when the market potential becomes high, the global firm has to deploy its technology transfer strategy to keep out the entrant by transferring less technology,  $x^h$ , than the base amount,  $x^m$ , and by erecting imitation barriers. When the market potential increases, the global firm has to withhold more technology to increase the barriers and fend off the entrant, i.e.,  $\frac{\partial x^h}{\partial \xi} < 0$ . This reduction may become so strong that the global firm transfers less than a duopolist in order to remain a monopolist (for high enough risk  $\alpha > \hat{\alpha}'$  where  $\hat{\alpha}' (> \hat{\alpha})$  is defined in the proof of Corollary 1 in Appendix B). As a result, we posit that, at MSA, as the Chinese market potential increases further (e.g., due to the increasing awareness of mining safety, stricter enforcement of legislation, and image problems due to a high death toll in the mining industry), MSA's reluctance to transfer technology should only increase. We observed the interesting internal tensions that surfaced between engineering, finance and marketing departments. Only when this strategy becomes too expensive, does the global firm accommodate the entrant by *increasing* the technology transfer amount from  $x^h$  to  $x^d$ . This is also counter-intuitive as, when allowing for imitation, the revenues have to be split, but yet more technology is transferred. The global firm is in fact relieved from the withholding strategy, and can now transfer the optimal duopoly technology amount, which will still be less than the base transfer amount that ignores competitive effects.

Sensitivity with respect to other parameters. Thus far, we have focused on market potential as the main determinant of the technology transfer strategy. We now discuss how the factor cost difference c, the transfer cost  $k^G$ , and the imitation cost  $k^L$ , change the technology transfer strategy. First, our numerical study (see Figure 4 in Appendix B) shows that the accommodation region increases when the cost difference c increases. This arises since when the cost difference is low, it is easy for the global firm to deter the imitator's entry. Second, with a higher transfer cost  $k^G$ , the global firm more likely will accommodate entry when the imitation risk is low, but more likely it will deter entry when the imitation risk is high (see a proof in Lemma 3). In the low-risk case, the global firm deters the imitator's entry by transferring more and therefore incurring higher transfer costs. When the transfer cost increases, the deterrence strategy becomes far more costly. The opposite occurs in the high-risk case because the global firm deters imitation by transferring less and therefore incurring lower transfer costs. The impact of the imitation cost  $k^L$  is likewise intuitive.  $k^L$  can alternatively be regarded as a measure of the imitation cost is likely to be high when the IP protection strength in emerging countries. The imitation cost is likely to be high when the IP protection laws are rigorously enforced. It can be shown that the global firm more likely will deter entry when the imitation cost  $k^L$  increases (see Lemma 3).

Numerical illustration. We now illustrate numerically the main insights obtained by our model. Figure 3 depicts the optimal technology transfer amount  $x^*$  as a function of market potential  $\xi$ . The left panel illustrates the case of low imitation risk. The technology transfer increases as the market potential increases and reaches a local maximum just before the global firm starts to scale back technology transfer to accommodate the imitator. When fending off the imitator using a "marketgrabbing strategy," more technology is transferred in an accelerated fashion as the market potential increases. The right panel illustrates the case of high imitation risk. In this case, the local maximum is reached just before the global firm starts to fend off the imitator using a "barrier-erecting strategy." When fending off an imitator, less technology is transferred as the market potential increases.

In the next subsection, we illustrate our findings by discussing stylized observations about the technology transfer strategies of firms in different industries.

#### 4.3 Interpreting Observed Firms' Strategies

In this subsection, we discuss qualitatively how our insights may be used to explain technology transfer strategies in different situations. Recall that our main parameters are the imitation risk, market potential, cost-saving potential, and transfer costs. We are interested in how much the firm should transfer compared with the base level  $x^m$  (i.e., the monopoly optimal transfer amount that ignores competitive effects). (We note here that our model is highly stylized and should not be used as a decision support tool.) The goal of the interpretation below is to sharpen managers' intuition about the proper strategy to employ in a given situation. Also, the data input is highly qualitative. Therefore, the discussion below is indicative and meant be used only as a starting point for crafting



Figure 3: Illustration of "Market-Grabbing Strategy" in (a), and "Barrier-Erecting Strategy" in (b): Over  $[\underline{\xi}, \overline{\xi}]$ , the transfer amount is more (less) than the base transfer amount,  $x^m$ , for low (high) risk. (In the low risk case (a), we use c = 0.5,  $\alpha = 0.2$ ,  $\gamma = 10$ ,  $k^G = 0.6$ , and  $k^L = 0.3$ ; and in the high risk case (b), we use c = 0.5,  $\alpha = 0.9$ ,  $\gamma = 10$ ,  $k^G = 0.2$ , and  $k^L = 0.4$ .)

	Prada	Apple	Netafim	$\mathbf{G}\mathbf{M}$
<b>Imitation risk:</b> $\alpha$ (compared with $\hat{\alpha}$ )	Low	Low	High	High
Market potential: $\xi$ (compared with $\overline{\xi}$ )	Low	High	Low	High
Cost saving potential: c	Low	High	Low	High
Transfer cost: $k^G$	Low	High	High	Low
Imitation cost: $k^L$	High	Low	High	Low
<b>Technology strategy</b> (compared with $x^m$ )	More	Less	Less	Less
Competitive strategy	$\mathbf{D}\mathbf{e}\mathbf{t}\mathbf{e}\mathbf{r}^{a}$	Acc.	$\operatorname{Deter}^{b}$	Acc.

new strategy. We summarize the examples mentioned in the introduction section in Table 2.

<sup>*a*</sup> "Market Grabbing", <sup>*b*</sup> "Barrier Erecting"

Table 2. Firms' technology and competitive strategies as a function of parameters.

For firms such as Prada and Apple, separating operations will likely not raise imitators' entry barriers, i.e., the imitation risk of transferring technology is low. Facing low local demand for its exclusive lines in developing countries such as Turkey and Eastern Europe, Prada transfers nearly all its technology so that its variable cost is reduced to a level similar to that of the local imitator. Also, imitators do not enter due to their low emerging market profit after entry. This behavior supports the "market-grabbing strategy." In the case of Apple, however, it is relatively difficult to prevent imitation because of high demand in the local markets. Apple transfers a part of its technology to Asia, and keeps the production of complex components at home to avoid high transfer costs. Facing such a competitor disadvantaged in variable cost, the imitators (e.g., Ainol) enter. In contrast, for firms such as Netafim and GM, keeping technology in the home country works well by raising imitators' entry costs. In other words, the imitation risk of transferring technology is high. Hence, in the case of low demand in the local market, the imitators' entry can be easily deterred by using the "barrier-erecting strategy." This is the situation with Netafim, which keeps high-imitation-risk components at home. In the case of GM, however it is difficult to prevent imitation because of high demand in the local markets. GM foregoes the deterrence option, and the high local market potential motivates GM to transfer nearly all its components in order to reap the highest possible cost-saving benefits. Though facing a competitor with a similar variable cost, the imitators (e.g., Chery with QQ) are able to enter due to the high local market potential.

## 5 Extension: Selling in the Home and the Emerging Market

In our base model, we assumed that the global firm does not source from the emerging market to its home market, and the two firms compete in the emerging market only. In this section, we extend our model by allowing the global firm to source for its home market. We hold the assumption that, due to IP protection in the home country, the local firm cannot export imitative goods to the global firm's home country. The global firm transports the components made by its local operations (home operations) to its home operations (local operations) and assembles them with the home-made (locally made) components for its demand in the home (emerging) market. An empirical study by Blalock and Veloso (2007) shows evidence that sourcing is a key driver of technology transfer. Ford and GM have production facilities in Brazil and Thailand, building vehicles not only for those local markets but also for the broader regional markets of South America and Southeast Asia, respectively (Hanson et al. 2001). Daimler-Chrysler AG had plans to build subcompacts in China that would be exported and sold in the U.S. (*Wall Street Journal* 2005a).

The global firm's profit from its home market is now determined by the amount of components transferred: As more components are transferred, the higher are the cost savings and resulting profit from its home market. We denote the market potentials of the local and home markets by  $\xi_1$  and  $\xi_2$ , respectively. In Stage III of the game, in the case of the imitator's entry, the global firm sets two output levels,  $q_1^G(x, y) \in [0, +\infty)$  and  $q_2(x, y) \in [0, +\infty)$ , to maximize its duopoly profit in the local and its monopoly profit in the home market, respectively.

Because the imitator has no access to the global firm's home market, the imitator's entry decision still solely depends on its profits from the emerging market. Compared with the base model, the global firm's net profit is increased by the monopoly profit from the home market. Hence, the main insights, such as the impact of imitation risk on the optimal transfer strategies (Propositions 4 and 5), and the sensitivity of the optimal transfer amount to the emerging market potential (Corollary 1) will remain the same. A new insight we obtain is that a trade-off between focusing on capturing the local market and focusing on sourcing for the home market does have an impact on the attractiveness of the deterrence vs. accommodation strategies. We frame this in the following proposition:

**Proposition 6** (1) There exists a critical emerging market potential  $\overline{\xi}_1$  such that the global firm deters the imitator's entry if  $\xi_1 \leq \overline{\xi}_1$ , and accommodates its entry otherwise.

(2) There exists a critical imitation risk  $\widehat{\alpha}''$  such that  $\frac{\partial \overline{\xi}_1}{\partial \xi_2} \ge 0$  if  $\alpha < \widehat{\alpha}''$ , and  $\frac{\partial \overline{\xi}_1}{\partial \xi_2} \le 0$  otherwise.

Proposition 6 explains the interplay between the home market potential, the emerging market potential and the imitation risk in shaping the global firm's preference as to deterrence vs. accommodation strategies. Because of different technology strategies employed by the global firm in different situations, capturing the local market and sourcing for the home market may or may not conflict with each other.

Recall that when the imitation risk is low  $(\alpha < \widehat{\alpha}'')$ , the global firm transfers a higher amount of technology in order to deter the entrant than that in the accommodation region (Corollary 1). Hence, the global firm benefits more from sourcing when deterring the entrant than when accommodating. The higher the home market potential, the larger this additional sourcing benefit. A higher home market potential, therefore, leads to a higher critical local market potential, above which the global firm switches to accommodation, i.e.,  $\frac{\partial \overline{\xi}_1}{\partial \xi_2} \geq 0$ . In other words, it is less likely that the global firm will accommodate the entrant with increasing home market potential  $\xi_2$ . Interestingly, with high imitation risk, the situation is reversed. When the risk is high ( $\alpha \geq \widehat{\alpha}''$ ), the global firm benefits less from sourcing when deterring the entrant than when accommodating. Therefore, it is more likely that the global firm will accommodate the entrant with increasing home market potential  $\xi_2$ , i.e.,  $\frac{\partial \overline{\xi}_1}{\partial \xi_2} \leq 0$ . In both cases, the accommodate the entrant with increasing home market potential  $\xi_2$ , i.e.,  $\frac{\partial \overline{\xi}_1}{\partial \xi_2} \leq 0$ . In both cases, the accommodation strategy becomes more attractive when the emerging market potential  $\xi_1$  increases.

Sometimes, imports of imitative products to home markets have continued for a number of years before the technology-laden IP cases are settled by courts (Levin et al. 1987). Hence, a situation can be considered whereby an imitator who enters the emerging market can also sell to the global firm's home market. It can be shown that, in such cases, the insights remain the same as in the above one-market case (see Proposition 10 in Appendix B), since the two firms' cost structures in the one market are the same as in the other market. In addition, we assume that the two markets are independent of each other. Therefore, adding another market to both firms does not change our main qualitative insights in section §4.

## 6 Extension: Heterogeneity in Cost-Saving Potential

In our discussion of component technologies in section §3, we assumed in the base model that all components result in the same cost savings and we considered heterogeneity with respect to imitation risk. The technology transfer strategy was easily understood: Whichever fraction is transferred should include the components with the lowest imitation risk. With this assumption, we were able to obtain analytical insights into the optimal technology transfer strategy in different environments. We found that the imitation risk and market potential were important determinants of the global firm's transfer strategy. In practice, however, different components may have a different cost-saving potential by transferring. The global firm's problem becomes more challenging if components with high (low) imitation risk have a high (low) cost-saving potential. There are reasons why this is the case. Typically, for components with higher complexity, greater cost savings can be realized because more operations are involved, requiring more labor and material. At the same time, the costs and risks associated with transferring complex components are also high. In this section, we analyze how our insights generated for the homogeneous cost-saving potential.

Recall that we have labeled the components from 0 to 1 and their volume is normalized to 1. In order to model the fact that each component has a different variable cost-saving potential, we introduce  $\gamma_c$ , the cost-saving heterogeneity, and re-label  $\gamma$  as  $\gamma_k$ . Now, it is not clear that components with the lowest imitation risk must be transferred first because they may have the lowest cost savings. Hence, the global firm must select a component "range" that should be transferred. We denote this range by  $\mathbf{x} = (\underline{x}, \overline{x}) \subseteq [0, 1]$ . We use the following functional form for the impact function  $F(\mathbf{x}; \gamma)$ :  $F(\mathbf{x}; \gamma) = \frac{(\overline{x}-\underline{x})[1+\gamma(\overline{x}+\underline{x})]}{1+\gamma}$ .<sup>8</sup> In the case with cost-saving heterogeneity, the global firm's variable cost takes the following form:

$$c\left(\mathbf{x}\right) = c\left[1 - F\left(\mathbf{x}; \gamma_{c}\right)\right].$$

Note that  $\overline{x} = \underline{x} = x$  implies the global firm keeps all component production in its home country,

<sup>&</sup>lt;sup>8</sup>In fact,  $F(\mathbf{x}; \gamma)$  is the integral of a linear function over the component range:  $F(x; \gamma) = \int_{\underline{x}}^{\overline{x}} \frac{1+2\gamma\theta}{\gamma+1} d\theta$ , i.e., instead of integrating from 0 (the component with the lowest fixed cost) to x, we now integrate from  $\underline{x}$  to  $\overline{x}$ .

in which case, the global firm's variable production cost is c(x, x) = c. At the other extreme, if all components are transferred to the local market, i.e.,  $(\underline{x}, \overline{x}) = (0, 1)$ , the global firm's variable cost is reduced to the same level as that of the local firm i.e., c(0, 1) = 0. Finally, we obtain that when  $\gamma_c = 0$ ,  $c(\underline{x} - \underline{x})$ , which corresponds to the homogeneous case in section §3. Similarly, the global firm's fixed transfer costs are given by:

$$K^{G} = k^{G} F\left(\mathbf{x}; \gamma_{k}\right),$$

and the imitator's imitation costs are given by:

$$K^{L}\left(\mathbf{x}\right) = k^{L}\left[1 - \alpha F\left(\mathbf{x}; \boldsymbol{\gamma}_{k}\right)\right].$$

The global firm faces a trade-off between avoiding high transfer costs (imitation risk) by transferring low cost-saving components, i.e., "low-end transfer," and reaping high cost-saving benefits by transferring high fixed-cost (imitation-risk) components, i.e., "high-end transfer." The relative values of the two heterogeneities determine which transfer strategy the global firm should adopt, as stated in the following proposition:

**Proposition 7** (1) When the transfer-cost heterogeneity is higher than the cost-saving heterogeneity, i.e.,  $\gamma_k > \gamma_c$ :  $\underline{x}^m = \underline{x}^d = \underline{x}^l = \underline{x}^h = 0$ ; (2) Otherwise:  $\overline{x}^m = \overline{x}^d = \overline{x}^l = \overline{x}^h = 1$ .

Proposition 7 suggests that the firm transfers those components which have higher (cost-saving) benefits relative to their (transfer) costs, in both its optimal monopoly decision,  $\mathbf{x}^m = (\underline{x}^m, \overline{x}^m)$ , and optimal duopoly decision,  $\mathbf{x}^d = (\underline{x}^d, \overline{x}^d)$ . These components can be either at the low end when  $\gamma_k > \gamma_c$ , i.e.,  $\underline{x}^m = \underline{x}^d = 0$ , or at the high end when  $\gamma_k \leq \gamma_c$ , i.e.,  $\overline{x}^m = \overline{x}^d = 1$ 

In the case of a potential imitator, the no-entry region is defined by:  $\mathbf{x} \in [\mathbf{x}^l, \mathbf{x}^h]$ , where  $\mathbf{x}^l = (\underline{x}^l, \overline{x}^l)$ , and  $\mathbf{x}^h = (\underline{x}^h, \overline{x}^h)$  define two indifferent transfer decisions at which the local firm's net profit is equal to zero. It is shown in Appendix that the global firm's duopoly profit in the entry region and monopoly profit in the no-entry region are both maximized at either the low end or high end. It then follows that the optimal transfer decision in the presence of an imitator always satisfies  $\underline{x}^* = 0$  when  $\gamma_k > \gamma_c$ , and  $\overline{x}^* = 1$  otherwise. In other words, the incorporation of component heterogeneity in cost-saving potential adds only a new insight into whether the firm should transfer low- or high-end components: "low-end transfer" if the cost-saving heterogeneity is lower than the transfer-cost (imitation-risk) heterogeneity, i.e.,  $\gamma_k > \gamma_c$ ; "high-end transfer" otherwise. Other insights in the base model still hold, as proven in Proposition 11.

Proposition 7 allows us a better understanding on the tension that we have observed, e.g., at MSA. When deciding which components of a self-contained breathing apparatus to transfer, a device to provide breathable are in hostile environments, MSA was interested in reaping benefits from "low-hanging fruit," i.e., transfer from easily transferable component technology (e.g., pressure hoses and facepiece). The downside is that the cost savings are low. Transferring more complex "hot" components (e.g., regulators, audible alarm and cylinder valve) is more complicated, thus expensive and exposes the firm to higher imitation risk, but results in more substantial cost savings. Proposition 7 suggests that the overall variable-cost profile as well as the fixed-cost profile must be first considered when making a decision. Depending on which profile exhibits more heterogeneity, a low- or high-end transfer strategy is chosen first. How many components to transfer, taking competitive reaction into account, is then determined by the same factors as in section §4 (i.e., market potential, imitation risk, cost-saving potential and transfer cost).

## 7 Conclusions

**Discussion:** We have studied imitative competition, motivated by problems faced by several companies in diverse industries who consider transferring technology to emerging markets for manufacturing. As codifying technology for the purpose of internal transfer facilitates the ease of unwanted imitation, firms must balance the need to lower manufacturing costs against the need to prevent technology unintentionally leaking to other firms. Considering that components differ in imitation risk and cost-saving potential, component-based technology transfer becomes a natural strategic instrument that firms can leverage. The instrument has a simultaneous impact on fixed entry costs, and post-entry competition. Hence, the market potential and imitation risk level are two critical factors that determine whether the global firm should deter or accommodate an imitator's entry, and if deter, how. The market potential, along with firms' cost-competitiveness, determine the emerging market profit the imitator can obtain in the case of entry, and hence the level of difficulty in deterring the imitator's entry. The imitation risk level determines whether raising the entry cost or grabbing the market is more effective in deterring the entrant. It is the interplay among the market characteristics, imitation risks and cost structures that makes this research interesting. Our paper derives the following important managerial insights.

Managerial Insights: First, the presence of an imitator can motivate the global firm to transfer less, but also in some cases more, than the base technology transfer amount when the market potential is neither low nor large. In the case of high imitation risk, the firm transfers a lower amount to deter the imitator's entry by keeping the imitator's entry cost high; while in the case of low imitation risk, the firm transfers a higher amount to deter by significantly reducing its variable costs and therefore competing aggressively to reduce the imitator's emerging market profit in the case of its entry. Second, in both cases, there are compelling reasons for transferring a lower amount when the market potential increases. In the case of low imitation risk, the global firm scales back the transfer amount and accommodates the entrant when it loses excessively by transferring a high amount in order to deter. In the case of high imitation risk, the global firm withholds more technology when the market potential increases in order to raise entry costs and deter the imitator's entry. Third, if sourcing opportunities are taken into account, in different risk cases, the potentials of the two markets have a different impact on the global firm's preference in deterrence vs. accommodation strategies: The accommodation strategy becomes less (more) attractive when the home market potential increases of low (high) imitation risk. Finally, when incorporating heterogeneity in cost-saving potential, the relative heterogeneity of the cost savings vs. the imitation risk determines which components need to be transferred first: High- or low-end. How many components to transfer is still determined by the competitive interaction detailed above.

**Contributions to the Literature:** Our paper complements the literature in the following ways. First, we introduce a new instrument of technology transfer at the component level by recognizing that technology differs in two dimensions: Complexity (transfer cost or imitation risk) and costsaving potential. This instrument hence connects technology transfer and imitation through both fixed and variable costs, which leads to the two different deterrence strategies. Prior entry-deterrence models either ignore the connection between firms' fixed entry costs, or ignore the impact of the postentry competition. Therefore, entry is deterred either by raising entrants' entry costs (e.g., Ethier and Markusen 1996), or by reducing their competition payoffs (e.g., Schmalensee 1978, Donnenfeld and Weber 1995). Second, when the models in the international Operations Management literature decide on the geographical dispersion of (component) production, particularly in emerging economies to leverage their comparative advantages in factor costs, technology imitation is generally ignored in the literature (e.g., Flaherty 1986, Cohen and Lee 1989, DuBois et al. 1993, Ferdows 1997). Our paper shows that by ignoring the strategic reaction of potential imitators in either emerging or existing markets, they may allocate too much or not enough production to these countries, and therefore forego new market revenues and/or sourcing benefits.

Limitations and Future Research: In order to focus on the key trade-offs, we have ignored transportation costs and tariffs, and assumed that firms compete on quantity, ignoring vertical or horizontal differentiation between the firms' products. In practice, tariffs and transportation costs

may be not be neglected. Furthermore, an imitator may deliver a product of lower quality than the global firm's product. In addition, global companies may look to differentiate themselves using assets that are not easily imitated by their competitors, e.g., brand and service. As a result, vertical differentiation between the global and local firm may be important. Also, local companies may know more about local consumers' taste and culture. Therefore, horizontal differentiation is another interesting dimension to consider. Finally, we do not consider that producing more components at the same location may save more production (e.g., setup) costs. These are unanswered questions that our model is left with.

Our model may also be extended in some other directions. One promising avenue for future research is to recognize both competition and cooperation between the global firms and the imitators. A manufacturing partnership with local companies will enable the global firm to produce at competitive cost, as well as give the global firm an opportunity to leapfrog the competition. However, the global firm also faces greater risk of creating a formidable competitor (*Wall Street Journal* 2006b). The second promising path is to incorporate the effects of several global firms competing or cooperating in emerging markets, while they are confronted with potential competition from local imitators. It would be interesting to study the impact of the rivalry or cooperation between firms on strategies of imitation, deterrence or accommodation by players engaged in these market dynamics.

Finally, one might view the emerging markets not just as product markets, but also as innovators for the global markets. Large market potential, low cost of factors, and pools of low-wage talent are big attractions of newly emerging markets. Pushed by these impetuses, companies such as Procter and Gamble, Motorola, and IBM have been investing to expand their Chinese R&D operations to develop products for global markets (*Wall Street Journal* 2006a). Inevitably, these firms all face obstacles, such as weak IP protections. With the advent of global R&D, such issues have come to the forefront: Will the prospects of eventual imitation dilute the gains for innovation? How does the sourcing strategy affect the innovation growth process? How do the market potentials affect the long-run rates of innovation and imitation? In addition, all these problems may be examined in a dynamic IP policy setting in which patent duration can play an important role. The answers to these questions are not readily apparent, and will require more research building on models such as those attempted in this paper. Imitation competition and innovation are fertile ground for fascinating modeling in the future, and we hope our research in this paper has made a promising start.

## Appendix A: Additional Analysis

In this Appendix, we elaborate three issues that have been mentioned in the text, but, not proven or explained. The first is an additional sensitivity analysis of the critical market potential,  $\overline{\xi}$ . The second is an analysis of the case in which the global firm does not perfectly know the emerging market potential,  $\xi$ . The third is an analysis of the case in which there are multiple imitators in the emerging market.

More Comparative Statics: Figure 4 shows the sensitivity of the critical market potential,  $\overline{\xi}$ , to the cost-saving potential c. The accommodation region is increasing in the cost-saving potential c.



Figure 4: Critical market potential  $\overline{\xi}$  as a function of cost saving potential c.

Uncertain Market Potential: We have assumed that the emerging market potential,  $\xi$ , is common knowledge. This may not always be the case. It is more likely that the local firm has a better view of the market potential  $\xi$  than does the global firm. In this Appendix, we introduce an uncertainty in the market potential  $\xi$ , in the single-market case. That global firms entering new economies do not have a perfect knowledge about the market potentials is a common issue. For example, western car makers over-invested in China, and Nestle and Unilever over-produced in the ice cream market in Saudi Arabia, due to their imperfect knowledge of the market potentials (*The Economist* 2003, Arnold 1998). We assume that market potential information,  $\xi \in {\xi_l, \xi_h}$ , is unobservable to the global firm, but is perfectly known by the local imitator. The global firm has a belief that the market potential is high  $\xi_l$  with probability p, and low  $\xi_h$  with probability 1 - p. We study how the local firm's information advantage impacts the technology transfer strategy.

The game proceeds as follows. In <u>Stage I</u>, the global firm decides what fraction of components, x, to transfer based on its belief about the market potential. In <u>Stage II</u>, the local firm decides whether or not to enter,  $y \in \{0, 1\}$ , after observing the realization of  $\xi$  and global firm's decision, x. In Stage III, the market potential information  $\xi$  is then revealed to the global firm also and the two

firms compete in quantities. We study the consequences of the global firm's imperfect knowledge of the emerging market potential. Imperfect knowledge leads to a lower imitator's Stage III equilibrium profit than that believed by the global firm believes (see Lemma 4 in Appendix B). This suggests that for any given market potential, the imitator's actual no-entry region is larger than that believed by the global firm. We then immediately have the following proposition:

**Proposition 8** Compared with perfect information about the market potential, imperfect knowledge causes the following:

(1) the global firm transfers more when deterring using a "market-grabbing strategy" in the low-risk case,

(2) the global firm transfers less when deterring using a "barrier-erecting strategy" in the high-risk case, and

(3) the critical market potential is lower, above which the imitator's entry is accommodated.

Proposition 8 suggests that the global firm's information disadvantage makes the global firm be too cautious when deterring the imitator's entry: It over-deters by transferring too much in the low-risk case when using the "market-grabbing strategy," while transferring too little in the high-risk case when using the "barrier-erecting strategy." In other words, the global firm incurs unnecessary costs in order to deter. On the other hand, the global firm's over-estimation of the imitator's ability to enter the market leads to a benefit enjoyed by the imitator: The imitator's entry is accommodated in a larger market potential region.

Multiple Imitators: In this subsection, we study the case of  $n \ge 2$  identical imitators. Each imitator  $k, k \in \{1, 2, ..., n\}$ , has the same variable cost  $c^L = 0$ , and the same imitation cost  $K^L(x)$ . It can be shown that both the global firm's and each imitator k's Stage III Cournot sub-game equilibrium profit are a decreasing function of the number of imitators n (see Lemma 5 in Appendix B). Hence, the imitators' no-entry region  $[x^l, x^h]$  increases with n, and the global firm's net profit  $\Pi^G(x, 1)$  in the case of the imitators' entry, decreases with n. We then have the following proposition:

**Proposition 9** As the number of imitators n increases, the critical market potential  $\overline{\xi}$  increases.

The increasing no-entry region means that it becomes easier to deter the imitators' entry when there are more imitators. The decreasing optimal net duopoly profit  $\Pi^{G*}(x^d, 1)$  of the global firm means that the accommodation strategy becomes less attractive when there are more imitators. Both make the deterrence region increase, i.e.,  $\frac{\partial \overline{\xi}}{\partial n} > 0$ .

## **Appendix B: Proofs**

**Lemma 2** The firms' Stage III Cournot sub-game equilibrium profits  $\pi^{G*}$  and  $\pi^{L*}$  are given by:

$$\pi^{G*}(x,1) = \frac{1}{9} \left[ \xi + c^L - 2c^G(x) \right]^2, \text{ and } \pi^{L*}(x,1) = \frac{1}{9} \left[ \xi + c^G(x) - 2c^L \right]^2.$$

The monopoly optimal profit is given by

$$\pi^{G*}(x,0) = \frac{1}{4} \left[\xi - c^G(x)\right]^2.$$

It holds that  $\frac{\partial \pi^{i*}(x,1)}{\partial c^i} = -\frac{4}{3}q^{i*} < 0, \ \frac{\partial \pi^{i*}(x,1)}{\partial c^{-i}} = \frac{2}{3}q^{i*} > 0, \ and \ \frac{\partial \pi^{G*}(x,0)}{\partial c^G} = -q^*.$ 

**Proof** of Lemma 2. If the imitator does not enter (y = 0), the global firm reaps monopoly profit  $\pi^{M}(q(x); x)$  by setting the output level q. If the imitator enters (y = 1), the firms' duopoly payoffs are  $\pi^{G}(q^{G}(x), q^{L}(x); x)$  and  $\pi^{L}(q^{G}(x), q^{L}(x); x)$ , given the output levels  $q^{G}$  and  $q^{L}$ . Let  $q^{*}(x)$  be the optimal monopoly quantity when the imitator does not enter (y = 0), which is given by:  $q^{*}(x) = \underset{q}{\operatorname{arg\,max}} \pi^{M}(q(x); x)$ , where,

$$\pi^{M}\left(q\left(x\right);x\right) = \left(\xi - q\left(x\right) - c^{G}\left(x\right)\right)q^{G}\left(x\right).$$

Denote the firms' Stage III Cournot sub-game equilibrium quantities in the case of the imitator's entry (y = 1) by:  $q^{G*}(x)$  and  $q^{L*}(x)$ , which are given by:

$$\begin{cases} q^{G*}\left(x\right) \in \operatorname*{arg\,max}_{q^{G}} \pi^{G}\left(q^{G}\left(x\right), q^{L*}\left(x\right); x\right) \\ q^{L*}\left(x\right) \in \operatorname{arg\,max}_{q^{L}} \pi^{L}\left(q^{G*}\left(x\right), q^{L}\left(x\right); x\right) \end{cases} \end{cases}$$

where,

$$\pi^{G} \left( q^{G}(x), q^{L}(x); x \right) = \left( \xi - q^{G}(x) - q^{L}(x) - c^{G}(x) \right) q^{G}(x),$$
$$\pi^{L} \left( q^{G}(x), q^{L}(x); x \right) = \left( \xi - q^{G}(x) - q^{L}(x) - c^{L} \right) q^{L}(x).$$

and  $c^{L} = 0$  is the local firm's variable cost. In the following, we derive equilibrium profits. In the duopoly case, by maximizing the firm *i*'s profits  $\pi^{i}$  with respect to its quantity  $q^{i}$ , we have the best response quantities:  $q^{i*}(q^{-i}) = \frac{1}{2}(\xi - q^{-i} - c^{i})$ . Solving the two equations for  $i = \{G, L\}$ gives equilibrium quantities:

$$q^{i*} = \frac{1}{3} \left( \xi + c^{-i} - 2c^i \right),$$

and the equilibrium profits as above. The monopoly case is straightforward, and the monopoly optimal quantity is given by  $q^{M*} = \frac{1}{2} (\xi - c^G)$ .

In the following, we show  $\frac{\partial \pi^{i*}}{\partial \hat{c}^i} = \alpha q^i \left( \hat{c}^i, \hat{c}^{-i} \right)$ , where  $\hat{c}^i = -c^i$ , and a > 0. From the FOC of  $\pi^i \left( P\left(q^i, q^{-i}\right) + \hat{c}^i \right)$  w.r.t.  $q^i$ , we have  $P + \hat{c}^i + q^i \frac{\partial P}{\partial q^i} = 0$ . Hence,

$$\begin{aligned} \frac{\partial \pi^{i*}}{\partial \widehat{c}^{i}} &= \frac{\partial q^{i}}{\partial \widehat{c}^{i}} \left[ P\left( q^{i}\left(\widehat{c}^{i}, \widehat{c}^{-i}\right), q^{-i}\left(\widehat{c}^{i}, \widehat{c}^{-i}\right) \right) + \widehat{c}^{i} \right] + q^{i}\left(\widehat{c}^{i}, \widehat{c}^{-i}\right) \left[ \frac{\partial P}{\partial q^{i}} \frac{\partial q^{i}}{\partial \widehat{c}^{i}} + \frac{\partial P}{\partial q^{-i}} \frac{\partial q^{-i}}{\partial \widehat{c}^{i}} + 1 \right] \\ &= q^{i}\left(\widehat{c}^{i}, \widehat{c}^{-i}\right) \left( \frac{\partial P}{\partial q^{-i}} \frac{\partial q^{-i}}{\partial \widehat{c}^{i}} + 1 \right), \end{aligned}$$

where,  $\frac{\partial P}{\partial q^{-i}} \frac{\partial q^{-i}}{\partial \widehat{c}^i} + 1 > 0$  because  $\frac{\partial P}{\partial q^{-i}}, \frac{\partial q^{-i}}{\partial \widehat{c}^i} < 0$ . Under the linear demand model,  $\frac{\partial P}{\partial q^{-i}} = -1$ ,  $\frac{\partial q^{-i}}{\partial \widehat{c}^i} = -\frac{1}{3}$ . Then,  $\frac{\partial \pi^{i*}}{\partial \widehat{c}^i} = \frac{4}{3}q^i (\widehat{c}^i, \widehat{c}^{-i})$ .

In the following we show  $\frac{\partial \pi^{i*}}{\partial \hat{c}^{-i}} = -\beta q^i \left(\hat{c}^i, \hat{c}^{-i}\right)$ , where  $\beta > 0$ . We have,

$$\begin{aligned} \frac{\partial \pi^{i*}}{\partial \widehat{c}^{-i}} &= \frac{\partial q^{i}}{\partial \widehat{c}^{-i}} \left[ P\left( q^{i}\left(\widehat{c}^{i}, \widehat{c}^{-i}\right), q^{-i}\left(\widehat{c}^{i}, \widehat{c}^{-i}\right) \right) + \widehat{c}^{i} \right] + q^{i}\left(\widehat{c}^{i}, \widehat{c}^{-i}\right) \left[ \frac{\partial P}{\partial q^{i}} \frac{\partial q^{i}}{\partial \widehat{c}^{-i}} + \frac{\partial P}{\partial q^{-i}} \frac{\partial q^{-i}}{\partial \widehat{c}^{-i}} \right] \\ &= q^{i}\left(\widehat{c}^{i}, \widehat{c}^{-i}\right) \frac{\partial P}{\partial q^{-i}} \frac{\partial q^{-i}}{\partial \widehat{c}^{-i}}, \end{aligned}$$

where,  $\frac{\partial P}{\partial q^{-i}} \frac{\partial q^{-i}}{\partial \hat{c}^i} < 0$  because  $\frac{\partial P}{\partial q^{-i}} < 0$ , and  $\frac{\partial q^{-i}}{\partial \hat{c}^{-i}} > 0$ . Under the linear demand model,  $\frac{\partial P}{\partial q^{-i}} = -1$ ,  $\frac{\partial q^{-i}}{\partial \hat{c}^{-i}} = \frac{2}{3}$ . Then,  $\frac{\partial \pi^{i*}}{\partial \hat{c}^{-i}} = -\frac{2}{3}q^i (\hat{c}^i, \hat{c}^{-i})$ . That  $\frac{\partial \pi^{M*}}{\partial \hat{c}^i} = q(\hat{c})$  follows a similar proof.

**Proof** of Proposition 1. (1) Monopoly case: Since the net profit is  $\Pi^{G}(x,0) = \frac{1}{4} \left[\xi - c(1-x)\right]^{2} - k^{G} \frac{x(1+\gamma x)}{1+\gamma}$ , we have

$$\frac{\partial \Pi^{G}\left(x,0\right)}{\partial x} = \frac{1}{2}c\left[\xi - c\left(1 - x\right)\right] - k^{G}\frac{1 + 2\gamma x}{1 + \gamma}, \text{ and } \frac{\partial^{2}\Pi^{G}\left(x,0\right)}{\partial x^{2}} = \frac{1}{2}c^{2} - \frac{2k^{G}\gamma}{1 + \gamma}$$

Then, the monopoly optimal amount is

$$c^{m} = \frac{k^{G} - c\left(\xi - c\right)\left(1 + \gamma\right)}{c^{2}\left(1 + \gamma\right) - 4k^{G}\gamma}$$

When  $\frac{1}{2}c^2 < \frac{2\gamma k^G}{1+\gamma}$ , the optimal  $x^*$  satisfies:  $\frac{\partial x^m}{\partial \xi} = \frac{-\frac{c}{2}}{\frac{1}{2}c^2 - \frac{2\gamma k^G}{1+\gamma}} > 0$ . Otherwise, the optimal  $x^*$  becomes:

$$r^m = \begin{cases} 0 & \xi < \frac{2k^G}{c} + \frac{c}{2} \\ 1 & o/w \end{cases}$$

 $\frac{\partial \Pi^{G}(x^{m},0)}{\partial \xi} > 0 \text{ is because } \frac{\partial^{2} \Pi^{G}(x,0)}{\partial x \partial \xi} = \frac{1}{2}c > 0.$ (2) Duopoly case: Since  $\Pi^{G}(x,1) = \frac{1}{9} \left[\xi - 2c \left(1-x\right)\right]^{2} - k^{G} \frac{x(1+\gamma x)}{1+\gamma}$ , we have:

$$x^{d} = \frac{9k^{G} - 4c(\xi - 2c)(1 + \gamma)}{8c^{2}(1 + \gamma) - 18\gamma k^{G}}$$

 $x^m > x^d$  is because  $\frac{\partial \Pi^G(x,0)}{\partial x} > \frac{\partial \Pi^G(x,1)}{\partial x}$  for any x. Other results follow the same proofs as above. **Proof** of Lemma 1. The imitator's profits in the case of entry is  $\Pi^L(x,1) = \frac{1}{9} \left[\xi + c(1-x)\right]^2 - \frac{1}{9} \left[\xi + c(1-x)\right]^2$   $k^L \left[1 - \alpha \frac{x(1+\gamma x)}{1+\gamma}\right]$ . Hence,

$$\begin{array}{ll} \displaystyle \frac{\partial \Pi^L}{\partial x} & = & \displaystyle -\frac{2}{9}c\left(\xi+c-cx\right)+\alpha k^L\frac{1+2\gamma x}{1+\gamma}, \mbox{ and } \\ \\ \displaystyle \frac{\partial^2 \Pi^L}{\partial x^2} & = & \displaystyle \frac{2}{9}c^2+\alpha k^L\frac{2\gamma}{1+\gamma}>0. \end{array}$$

**Proof** of Proposition 2. Results immediately follow from the convexity of  $\Pi^{L}(x, 1)$ , and  $\frac{\partial \Pi^{L}(x, 1)}{\partial \xi} > 0$  for any x.

Note that at  $\xi = \hat{\xi}$ , we have  $\arg \min \Pi^L(x, 1) = 0$ , and  $\hat{\xi}$  satisfies:

$$\left[9\alpha k^{L} - 2c\left(\widehat{\xi} + c\right)\left(1 + \gamma\right)\right]^{2} - 4\left(1 + \gamma\right)\left[\left(\widehat{\xi} + c\right)^{2} - 9k^{L}\right]\left[c^{2}\left(1 + \gamma\right) + 9\alpha k^{L}\gamma\right] = 0 \qquad (9)$$

**Proof** of Proposition 3. Because at  $\xi = \hat{\xi}$ ,

$$\widehat{x} \doteq x^{l} = x^{h} = \frac{2c\left(\widehat{\xi} + c\right)(1+\gamma) - 9\alpha k^{L}}{2\left[c^{2}\left(1+\gamma\right) + 9\alpha k^{L}\gamma\right]}$$
(10)

decrease with  $\alpha$ . Hence, there exists a critical risk  $\hat{\alpha}$ , such that, when  $\xi = \hat{\xi}$ : If  $\alpha < \hat{\alpha}$ ,  $\hat{x}$  is greater than the optimal monopoly amount  $x^m$ ; otherwise, lower, i.e.,

$$\begin{cases} \widehat{x} > x^m & \text{if } \alpha < \widehat{\alpha} \\ \widehat{x} \le x^m & \text{otherwise} \end{cases}.$$
(11)

Results then follow from the continuity.  $\blacksquare$ 

**Proof** of Propositions 4 and 5. Results immediately follow from Proposition 3. ■

**Proof** of Corollary 1. (i) When  $\alpha < \hat{\alpha}$ , for  $\xi > \underline{\xi}$ , we know  $x^m < x^l$ . Hence, at  $\xi = \overline{\xi}$ ,  $x^l > x^d$ , because  $x^d < x^m$  for all  $\xi$ .

(ii) Define a critical risk  $\hat{\alpha}'$ , such that, when  $\xi = \hat{\xi}$ : If  $\alpha < \hat{\alpha}'$ ,  $\hat{x}$  is greater than the optimal duopoly amount  $x^d$ ; otherwise, lower. We then have  $\hat{\alpha} > \hat{\alpha}'$  because  $x^d < x^m$ . Hence, it follows that at  $\xi = \bar{\xi}$ ,

$$\begin{cases} x^h < x^d & \text{if } \alpha > \widehat{\alpha}' \\ x^h \ge x^d & \text{otherwise} \end{cases}$$
(12)

**Lemma 3** (1)  $\frac{\partial \overline{\xi}}{\partial k^L} > 0$ , and (2)  $\frac{\partial \overline{\xi}}{\partial k^G} < 0$  if  $\alpha < \widehat{\alpha}'$ ,  $\frac{\partial \overline{\xi}}{\partial k^G} > 0$  otherwise.

**Proof** of Lemma 3. (1) is because  $\frac{\partial K^L(x,1)}{\partial k^L} < 0$ , and  $\frac{\partial \pi^{L*}(x,1)}{\partial k^L} = 0$ . (2) is because  $\frac{\partial K^G(x)}{\partial k^G} < 0$ ,  $\frac{\partial^2 K^G(x)}{\partial k^G \partial x} < 0$ , (12), and  $\frac{\partial \pi^{G*}(x,1)}{\partial k^G} = 0$ .

**Proposition 10** In the two-market case, there exists a critical market potential  $\overline{\xi}_1$  and a critical imitation risk  $\widehat{\alpha}$ , such that:

	$\xi \leq \overline{\xi}_1$	$\xi > \overline{\xi}_1$
$\alpha \geq \hat{\alpha} : \mathbf{x}^* =$	$\min\left[x^m,x^h\right]$	$x^d$
$\alpha < \widehat{\alpha} \colon \mathbf{x}^* =$	$\max\left[x^m, x^l\right]$	$x^d$

where,  $x^m, x^d, x^h, x^l$ , are defined the same way as in the base case.

**Proof** of Proposition 10. The Stage III sub-game equilibrium net profits are given by: if the imitator has no access to the home market:

$$\Pi^{G}(x,y) = \begin{cases} \Sigma_{j=1}^{2} \frac{1}{4} \left[\xi_{j} - c^{G}(x)\right]^{2} - K^{G}(x) & y = 0\\ \frac{1}{9} \left[\xi_{1} - 2c^{G}(x)\right]^{2} + \frac{1}{4} \left[\xi_{2} - c^{G}(x)\right]^{2} - K^{G}(x) & y = 1 \end{cases},$$
(13)

$$\Pi^{L}(x,y) = \begin{cases} 0 & y = 0\\ \frac{1}{9} \left[\xi_{1} + c^{G}(x)\right]^{2} - K^{L}(x) & y = 1 \end{cases}$$
(14)

if the imitator has access to the home market:

$$\Pi^{G}(x,y) = \begin{cases} \Sigma_{j=1}^{2} \frac{1}{4} \left[ \xi_{j} - c^{G}(x) \right]^{2} - K^{G}(x) & y = 0\\ \Sigma_{j=1}^{2} \frac{1}{9} \left[ \xi_{j} - 2c^{G}(x) \right]^{2} - K^{G}(x) & y = 1 \end{cases},$$
(15)

$$\Pi^{L}(x,y) = \begin{cases} 0 & y = 0\\ \Sigma_{j=1}^{2} \frac{1}{9} \left[ \xi_{j} + c^{G}(x) \right]^{2} - K^{L}(x) & y = 1 \end{cases}$$
(16)

In both case, it is immediate that the local firm's net profit  $\Pi^L(x, 1)$  is convex in x. Other results follow the same proofs as in the base case.

**Proof** of Proposition 6. The critical potential  $\overline{\xi}_1$  is defined as in (8), with net profit  $\Pi^G(x, y)$  defined in (13). The critical risk  $\widehat{\alpha}''$  is defined in the same way as in the proof of Corollary 1.

(1) If  $\alpha < \widehat{\alpha}''$ , for a given  $\xi_2$ , similar to the one-market case (Corollary 1), we know that the firm transfers more (to deter) at  $\xi_1 = \overline{\xi}_1 - \varepsilon$ , than at  $\xi_1 = \overline{\xi}_1 + \varepsilon$  (to accommodate). When there is a small increase in  $\xi_2$ , the increase in the global firm's monopoly profit from the home market must increase more at  $\overline{\xi}_1 - \varepsilon$  than at  $\overline{\xi}_1 + \varepsilon$ . This leads to a higher critical potential  $\overline{\xi}_1$ .

(2) If  $\alpha > \widehat{\alpha}''$ , this is on the contrary.

**Proof** of Proposition 7. In the following proof, we use the transformed decision variables (u, v), where  $u \doteq (\overline{x} - \underline{x})$ , and  $v \doteq (\overline{x} + \underline{x})$ . Hence, F function becomes:  $F(u, v, \gamma) = \frac{u(1+\gamma v)}{1+\gamma}$ , and  $v \in [u^2/2, (2-u)u/2]$  for any  $u \in [0,1]$ . For any amount  $u \in [0,1]$ ,  $v = u^2/2$  represents transferring low-end components, i.e.,  $\underline{x} = 0$ ; while v = (2-u)u/2 represents transferring high-end components, i.e.,  $\overline{x} = 1$  (there is a one-to-one mapping between (u, v) and  $(\underline{x}, \overline{x})$ ). (1) We first study the monopoly case. From  $\Pi^{G}((u,v),0) = \pi^{M*}(c^{G}(u,v)) - K^{G}(u,v)$  and  $\frac{\partial \pi^{M*}(c)}{\partial c} = -q(c) < 0$ , we have:

$$\begin{split} \frac{\partial \Pi^{G}\left(\left(u,v\right),0\right)}{\partial u} &= q\left(c\left(u,v\right)\right)\frac{c}{1+\gamma_{c}} - \frac{k^{G}}{\left(1+\gamma_{k}\right)},\\ \frac{\partial \Pi^{G}\left(\left(u,v\right),0\right)}{\partial v} &= q\left(c\left(u,v\right)\right)\frac{c}{1+\gamma_{c}}\gamma_{c} - \frac{k^{G}}{\left(1+\gamma_{k}\right)}\gamma_{k},\\ \frac{\partial^{2}\Pi^{G}\left(\left(u,v\right),0\right)}{\partial u^{2}} &= -\frac{\partial q\left(c\left(u,v\right)\right)}{\partial c\left(u,v\right)}\left(\frac{c}{1+\gamma_{c}}\right)^{2} > 0,\\ \frac{\partial^{2}\Pi^{G}\left(\left(u,v\right),0\right)}{\partial v^{2}} &= -\frac{\partial q\left(c\left(u,v\right)\right)}{\partial c\left(u,v\right)}\left(\frac{c}{1+\gamma_{c}}\right)^{2}\gamma_{c} > 0, \end{split}$$

where  $\frac{\partial q(c)}{\partial c} \leq 0$ , and in the case of a linear demand function,  $\frac{\partial q(c)}{\partial c} = -\frac{1}{2}$ . We then know: (i) If  $\gamma_c > \gamma_k$ . There are three possibilities: (i)  $\frac{\partial \Pi^G}{\partial u} > 0$ ,  $\frac{\partial \Pi^G}{\partial v} > 0$ , (ii)  $\frac{\partial \Pi^G}{\partial u} < 0$ ,  $\frac{\partial \Pi^G}{\partial v} < 0$ , and (iii)  $\frac{\partial \Pi^G}{\partial u} > 0$ ,  $\frac{\partial \Pi^G}{\partial v} < 0$ . In all cases,  $\Pi^G$  must be maximized on the upper boundary v = (2 - u) u/2. (ii) If  $\gamma_c < \gamma_k$ . There are three possibilities: (i)  $\frac{\partial \Pi^G}{\partial u} > 0$ ,  $\frac{\partial \Pi^G}{\partial v} > 0$ , (ii)  $\frac{\partial \Pi^G}{\partial u} < 0$ ,  $\frac{\partial \Pi^G}{\partial v} < 0$ , and (iii)  $\frac{\partial \Pi^G}{\partial u} < 0$ ,  $\frac{\partial \Pi^G}{\partial v} > 0$ . In all cases,  $\Pi^G$  must be maximized on the lower boundary  $v = u^2/2$ . (iii) If  $\gamma_c = \gamma_k$ .  $\frac{\partial \Pi^G}{\partial u}$  and  $\frac{\partial \Pi^G}{\partial v}$  take the same sign. Hence,  $\Pi^G$  must be maximized at either (u, v) = (0, 0), or (u, v) = (1, 1).

Similarly, the global firm's duopoly profit  $\Pi^{G}((u, v), 1)$  is maximized at the upper (lower) bound when  $\gamma_{c} > \gamma_{k}$  ( $\gamma_{c} \leq \gamma_{k}$ ).

(2) In the following, we want to show that in the case of the imitator's entry, we have:

(i)  $\Pi^{G}((u, v), 1)$ , in the entry region  $\{(u, v) | \Pi^{L}((u, v), 1) > 0\}$ , is maximized at the lower bound, i.e.,  $v = u^{2}/2$ , when  $\gamma_{c} \leq \gamma_{k}$ ; the upper bound, i.e., v = (2 - u) u/2, when  $\gamma_{c} > \gamma_{k}$ .

(ii)  $\Pi^{G}((u, v), 0)$ , in the no-entry region  $\{(u, v) | \Pi^{L}((u, v), 1) \leq 0\}$ , is maximized at  $v = u^{2}/2$  when  $\gamma_{c} \leq \gamma_{k}$ ; at v = (2 - u) u/2 otherwise. In particular,  $\Pi^{G}((u, v), 0)$  is monotonically increasing or decreasing on the boundaries.

If (i) and (ii) hold, we then know the global firm's optimal transfer decision is always at  $v = u^2/2$ (v = (2 - u) u/2) when  $\gamma_c > \gamma_k \ (\gamma_c \le \gamma_k)$ .

(i) It is similar to (1).

(ii) Assume  $\gamma_c=\gamma_k=\gamma.$  Define a curve in the (u,v) space:

$$\{(u, v) : \Pi^{L}((u, v), 1) = C\}$$

where  $C \leq 0$  is a constan. Because  $\Pi^L((u, v), 1)$  is a function of  $w \doteq \frac{u+\gamma v}{1+\gamma}$  ( $\Pi^G((u, v), 0)$  as well), the curve solves for a variable  $w \doteq \frac{u+\gamma v}{1+\gamma}$ , for a given C. Hence, the global firm's monopoly profit  $\Pi^G((u, v), 0)$  must be a constant on the curve, or for any (u, v) such that  $\frac{u+\gamma v}{1+\gamma} = w$ . This holds true for any given constant  $C \leq 0$ . Hence, the maximum value of  $\Pi^G((u, v), 0)$  on both upper and lower bounds must be the same.

If  $\gamma_c$  increases (say, by  $\varepsilon$ ),  $c^G(u, (2-u)u/2)$  decreases for any given u, while  $c^G(u, u^2/2)$  increases for any given u. Hence, the global firm's profit on the upper (lower) bound must increase (decrease). At the same time, the size of no-entry region on the upper (lower) bound must increase (decrease). This leads to an increase in the global firm's maximum monopoly profit on the upper bound, while a decrease on the lower bound. The continuity leads to the above conclusion.

**Proposition 11** With two heterogeneities,  $\gamma_c$  and  $\gamma_k$ , there exists a critical market potential  $\overline{\xi}$  and a critical imitation risk  $\hat{\alpha}$ , such that:

	$\xi \leq \overline{\xi}$	$\xi > \overline{\xi}$
$\alpha > \widehat{\alpha} \cdot \mathbf{x}^* -$	$\int \left(0, \min\left[\overline{x}^m, \overline{x}^h\right]\right)  \gamma_c < \gamma_b$	$_{k} \qquad \int  \left(0, \overline{x}^{d}\right)  \gamma_{c} < \gamma_{k}$
$\alpha \geq \alpha$ . $\mathbf{x} = $	$\left(\min\left[\underline{x}^{m}, \underline{x}^{h}\right], 1\right)  \gamma_{c} \geq \gamma_{b}$	$_{k}$ $\left( \underline{x}^{d}, 1 \right)  \gamma_{c} \geq \gamma_{k}$
$\alpha < \widehat{\alpha} \cdot \mathbf{x}^* - \mathbf{x}$	$\int \left(0, \max\left[\overline{x}^m, \overline{x}^l\right]\right)  \gamma_c < \gamma_b$	$_{k} \qquad \int \ \left(0, \overline{x}^{d}\right)  \gamma_{c} < \gamma_{k}$
	$\left( \left( \max\left[\underline{x}^{m}, \underline{x}^{l}\right], 1 \right)  \gamma_{c} \geq \gamma_{b} \right)$	$_{k}$ $\left( \underline{x}^{d}, 1 \right)  \gamma_{c} \geq \gamma_{k}$

**Proof** of Proposition 11. According to Proposition 7, the global firm transfer's decision is at either the high-end (v = (2 - u)u/2) or low-end  $(v = u^2/2)$ . In either case, it is easy to check that the local firm's net profit  $\Pi^L((u, v), 1)$  is convex in either u or v. Other results follow the same proofs as in the base case.

**Lemma 4** If the global firm has a belief that  $\xi = \xi_l$  with probability p, and  $\xi = \xi_h$  with probability 1 - p, and  $p\xi_l + (1 - p)\xi_h = \xi$ , the local firm obtains lower Stage III equilibrium profit than what the global firm believes, i.e.,  $\pi^{L*}(x, 1) < \tilde{\pi}^{L*}(x, 1)$ .

Proof of Lemma 4. The firms' Stage III equilibrium (expected) profits are given by:

$$\begin{split} \widetilde{\pi}^{G*} \left( x, 1 \right) &= \frac{1}{9} \left[ p \left( \xi_l + c^L - 2c^G \left( x \right) \right)^2 + (1-p) \left( \xi_h + c^L - 2c^G \left( x \right) \right)^2 \right], \text{ and} \\ \pi^{L*} \left( x, 1 \right) &= \frac{1}{9} \left( \xi + c^G \left( x \right) - 2c^L \right)^2. \end{split}$$

From the viewpoint of the global firm, the local firm's (expected) profit is given by:

$$\widetilde{\pi}^{L*}(x,1) = \frac{1}{9} \left[ p \left( \xi_l + c^G(x) - 2c^L \right)^2 + (1-p) \left( \xi_h + c^G(x) - 2c^L \right)^2 \right]$$

Then,  $\widetilde{\pi}^{L*} - \pi^{L*} = \frac{1}{9}p(1-p)(\xi_l - \xi_h)^2 > 0.$ 

**Proof** of Proposition 8. It immediately follows from Lemma 4.  $\blacksquare$ 

**Lemma 5** The firms' Stage III Cournot sub-game equilibrium global firm's and imitator k's profits  $\pi^{G*}(x,1)$  and  $\pi_k^{L*}(x,1)$  satisfy  $\frac{\partial \pi^{G*}(x,1)}{\partial n}, \frac{\partial \pi_k^{L*}(x,1)}{\partial n} < 0.$ 

**Proof** of Lemma 5. If the *n* identical imitators enter, the global firm's and imitator *k*'s,  $k \in \{1, 2, ..., n\}$ , Stage III payoffs are given by

$$\begin{aligned} \pi^{G}\left(x,1\right) &= \left[\xi - q^{G} - nq_{k}^{L} - c^{G}\left(x\right)\right]q^{G}, \text{ and} \\ \pi_{k}^{L}\left(x,1\right) &= \left[\xi - q^{G} - q_{k}^{L} - (n-1)q_{-k}^{L}\right]q_{k}^{L}. \end{aligned}$$

Solving  $\frac{\partial \pi^G}{\partial q^G} = 0$ ,  $\frac{\partial \pi^L_k}{\partial q^L_k} = 0$ , and  $q^L_k = q^L_{-k} = q^L$ , we obtain optimal quantities:

$$q^{G*} = \frac{1}{2+n} \left[ \xi - (n+1) c^G \right], \ q^{L*} = \frac{1}{2+n} \left( \xi + c^G \right),$$

and equilibrium profits:

$$\pi^{G*}(x,1) = \frac{1}{(2+n)^2} \left[ \xi - (n+1) c^G(x) \right]^2, \text{ and}$$
  
$$\pi^{L*}_k(x,1) = \frac{1}{(2+n)^2} \left[ \xi + c^G(x) \right]^2.$$

It follows that  $\frac{\partial \pi^{G^*}(x,1)}{\partial n}, \frac{\partial \pi_k^{L^*}(x,1)}{\partial n} < 0.$ 

**Proof** of Proposition 9. It immediately follows from Lemma 5.  $\blacksquare$ 

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