The Production, Transfer and Spillover of Technology: Comparing Large and Small Multinationals as Technology Producers

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ABSTRACT. Multinational enterprises are, *sina qua non*, the world's technology producers. In this paper, we explore the concept of technology production by multinationals, focusing on three aspects: (i) technology as a firm-specific advantage, (ii) the costs of technology transfer, and (iii) technology spillovers. In each case, we outline current views and debates in the field about the role played by large multinationals in technology production. Finally, we compare MNEs with small and medium sized enterprises (SMEs) as technology producers. We conclude that SMEs face certain constraints, due to small size and inadequate financing, that raise their costs of technology production and transfer, relative to the costs for MNEs. On the other hand, their flexibility and use of unconventional methods can create successful mini-nationals in niche markets.

1. Introduction

It is now a cliché to say that multinational enterprises (MNEs) produce, control and own most of the world's technology. The various issues of the UNCTC's *World Investment Report* have provided extraordinary detail about the technological activities of MNEs.[1] For example, we know that in the OECD countries about 80 percent of R&D activities of private firms take place in firms with more than 10,000 employees. Between 75–80 percent of all private R&D expenditures worldwide are accounted for by multinationals (Dunning, 1993, p. 290).

In addition, most technology production by MNEs takes place at home. U.S. multinationals, for example, perform only about 13 percent of their R&D offshore. In the late 1980s, over 80 percent of all R&D expenditures occurred in five countries: the U.S., Japan, France, the U.K. and West Germany (Dunning, 1993, p. 300). In instances where R&D facilities are located abroad, such action is generally pursued to customize products for local markets or meet local content requirements (OTA, 1994, p. 76).

Technology transfer among multinational organizations, whether they be large or small, has also been the subject of much research (Buckley, 1995; Dunning, 1988; Kogut and Zander, 1995; McFetridge, 1994; UNCTC, 1992). In general, this body of research has led to the conclusion that organizations engage in the transfer of technology in order to profit directly from the transfer (as in licensing arrangements), profit indirectly from the dissemination of the product or process (e.g., establishing industry standards), or in order to enable foreign affiliates to utilize organization-specific technologies in their operations.

Further, technology transfer from MNEs to host countries is the primary mechanism by which developing countries receive technology (Caves, 1996; Dunning, 1993; UNCTC, 1992). Most royalties, license and management fees – forms of payment for technology – are in-house payments, flowing from MNE subsidiaries to their parent firms. For example, over 90 percent of technology payments to foreigners made by Canadian subsidiaries of U.S. multinationals are intrafirm transfers to their U.S. parents (Eden, forthcoming, Ch. 4).

The above statistical picture suggests that multinationals are, *sina qua non*, the world's technology producers. In this paper, we review the literature on MNEs and technology, focusing specifically on three aspects: (i) technology as a

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firm-specific advantage, (ii) the costs of technology transfer, and (iii) technology spillovers. In each case, we outline current views and debates in the field about the role played by large multinationals in technology production. We then compare the ability of MNEs to produce and profit from technology with that of small and medium sized enterprises (SMEs). We conclude that, although SMEs face certain constraints on technological productivity which their larger counterparts do not face, this does not preclude SMEs from contributing, often significantly, to technological advancement. However, MNEs are likely to remain synonymous with knowledge production.

2. Technology as a firm-specific advantage

The literature on multinational enterprises and foreign direct investment (FDI) suggests that knowledge is the key source of ownership or firm-specific advantage (FSA) held by multinationals. The MNE goes abroad to earn rents on its store of knowledge, and the creation and exploitation of that knowledge is the main reason for the success and growth of the multinational over time (see, for example, Caves, 1996, Ch. 1; Dunning, 1988, 1993, Chs. 11 and 12; Johnson, 1970). Given this focus on knowledge, three perspectives describing how knowledge determines the expansion tendencies of MNEs have emerged.

According to the *public goods perspective*, knowledge is conceptualized as a public intermediate good owned by the firm which can be transferred at zero (or negligible) marginal cost to various units within the MNE (Johnson, 1970). Given the ease of transfer, a critical concern for the MNE is the potential for unintended transfer to, and expropriation of that knowledge by, competitors. As such, the public goods perspective suggests that MNEs will internalize transactions when transacting in the external market poses a significant risk of knowledge appropriation by competitors that would dissipate the MNE's knowledge-based FSA. Such cases are likely where property rights to the knowledge have not been assigned or are not effective (e.g. countries without patent protection).

The *internalization perspective* suggests that the decision by the MNE to organize outside of its home country rests in the costs of transferring knowledge to those distant locations. While this perspective recognizes the public good aspect of knowledge, the focus is more on the weight of bureaucratic costs (costs of hierarchical organization) relative to transaction costs (costs of transacting through the market) in determining expansion. MNEs will internalize divisions in host countries at that point where the costs of increased bureaucratization are just outweighed by the transaction costs associated with market contracting (Hennart, 1991; Buckley and Casson, 1976; Rugman, 1981).

The *technological competence perspective* also attaches primacy to knowledge in determining the expansion activities of MNEs (Cantwell, 1989, 1991, 1994). This perspective is different from the other two in that the importance of technological competence in determining an MNE's competitive advantage is stressed over knowledge transfer costs. In this framework, the MNE is not simply a mechanism through which costs are reduced but, rather, a vehicle through which knowledge is recombined (à la Schumpter, 1934) to produce and subsequently exploit new and valuable innovations (Kogut and Zander, 1992, 1993, 1995). A firm's facility in accomplishing recombination and exploitation is unique to that firm. As such, that knowledge remains firm-specific or *tacit*.

These three perspectives are reviewed in more detail below.

The public goods perspective

The OLI, or eclectic, paradigm developed by John Dunning (1988) suggests that MNEs choose their markets and structures according to three factors – ownership (O) or firm-specific advantages or competencies, locational (L) advantages inherent in particular geographic areas, and internalization (I) advantages derived from conducting transactions hierarchically rather than in the open market. In the OLI paradigm, ownership advantages are the key source of the MNE's competitive advantage in foreign markets.

FSAs arise from "privileged possession of intangible assets" and advantages from common governance of crossborder activities (Dunning, 1988, p. 79). These O advantages have four characteristics: (i) the firm owns or can appropriate the assets or their services; (ii) the assets

differ in productivity from comparable assets possessed by competing firms; (iii) they are mobile between national markets in which the MNE competes; (iv) they may be depreciable or augmentable but their life spans are not short relative to the firm's investment horizon (Caves, 1996). The traditional view of FSAs suggests that the primary advantage an MNE brings to foreign markets is its possession of superior knowledge; i.e. its most important proprietary asset is technology or knowledge.[2] Once technology is produced, it generates income through sales of goods or services embodying the technology.

Since Hymer's 1960 dissertation on the monopolistic advantages of the MNE (Hymer, 1976 [1960]), a central issue in the theory of foreign direct investment has been the nature of FSAs and their transfer across borders. FSAs are seen as proprietary assets that the firm can use but may not necessarily be able transfer to external parties. In order for the assets to be proprietary, either the firm must hold legal title to their use, or the assets cannot be easily copied or appropriated by other firms. That is, the benefits derivable from the use of FSAs remain the exclusive domain of the possessing firm. Because foreign markets offer the opportunity to earn additional rents over and above those in the home market, FSAs provide a rationale for expansion into foreign markets (the "why go abroad?" question in the OLI paradigm).

According to this perspective, technology (or knowledge) created and used within MNEs often has the characteristics of a public good, so it is difficult for the MNE to appropriate all the returns expected from its use (Johnson, 1970). Public goods have two characteristics: jointness in consumption[3] and nonexcludability.[4] As a public good, knowledge is easy to transfer but hard to protect. The twin characteristics of jointness and nonexcludability imply that the private market cannot efficiently price knowledge. Transfer through the external market will be difficult to price because of the high probability of free riding and opportunistic behaviour.

Patents provide the MNE with some relief from the second characteristic, nonexcludability, by giving the firm a property right to knowledge. However, not all forms of knowledge are patentable, and patents are not a perfect panacea for nonexcludability. Protecting the knowledge advantages of the MNE from free riding and opportunistic behaviour by possible competitors is therefore a key to ensuring the long run competitive advantage of the firm. As a result, the firm will choose to transfer technology primarily through wholly-owned subsidiaries rather than use external methods. Because technology which is relatively public has the jointness characteristic, the marginal cost of transfer within the MNE is low or zero. Thus the internal mobility of knowledge within the MNE, together with the need to prevent its dissipation to outsiders, implies that production and transfer of this type of technology will take place primarily within multinationals.

The publicness of knowledge therefore provides a rationale for the multinational's preference for wholly-owned subsidiaries as the vehicle for transferring technology to foreign countries. That is, FDI via wholly-owned subsidiaries is the transfer of the intermediate good – technology which embodies an MNE's firm-specific advantage – to host countries.

The internalization perspective

Whereas the focus of the public goods perspective is on the MNE's *possession* of unique knowledge, the internalization perspective is distinct in its concentration on the factors affecting the *transfer* of that knowledge (Buckley and Casson, 1976; Hennart, 1991; Rugman, 1981, 1986). For example, Hood and Young (1979, p. 56) suggest that, from the internalization perspective, "it is not the possession of a unique asset *per se* which gives a firm its advantage. Rather it is the process of internalizing that asset as opposed to selling it to a foreign producer which gives the MNE its unique advantage." Internalization decisions therefore rest on the relative weights of bureaucratic and transaction costs. The MNE internalizes these transactions as long as the costs of hierarchical organization are outweighed by the costs of knowledge transfer via the market mechanism.

Such internalization considerations arise as markets for the efficient transfer of knowledge fail. Ideally, in neoclassical theory, ambiguities in the valuing of a good are precluded as all information regarding a good's exchange value is imputed in its market price. In the international context, however, markets for knowledge fail as

"there is no simple interaction of supply and demand to set a market price" (Rugman, 1981, p. 41). As such, firms intending to sell their knowledge resources in international settings may find the appropriation of associated returns difficult. Conflicting interests among transacting parties may impede the establishment of appropriate transfer prices.

Furthermore, because of the scarcity and value of knowledge and technology assets, the MNE may be subject to opportunism in dealing with external parties which seek to expropriate those assets. In these cases, internalization theory suggests that the MNE will internalize the utilization, exploitation and transfer of knowledge rather than risk expropriation through the market mechanism.

The technological competence perspective

Cantwell (1991, p. 50) suggests that "technological competence . . . because it consists of those elements of a firm's technology which are distinctive, is never itself transferred through trade or copied exactly through spillovers to other firms." Technological competence, rather, is unique to each firm. It is tacit, being largely incomprehensible to competitors. This knowledge resides in the shared norms or routines of the firm's employees (Nelson and Winter, 1982) and the ability of those employees to reconfigure those routines (i.e., combinative capabilities per Kogut and Zander, 1992) to produce novel knowledge. Whereas patents of more codifiable knowledge may provide temporary FSAs to the firm (i.e., they can be bought, sold and used by others at a cost), tacit knowledge is much more difficult to imitate.

The development of tacit knowledge is viewed as a function of the evolutionary development of the firm (Nelson and Winter, 1982; Kogut and Zander, 1995; Teece, 1988). As a firm travels through economic space, it confronts numerous environmental stimuli. As it attempts to utilize its resources in order to profit from these environmental conditions, the firm gains an increased cognizance of its strengths and weaknesses. Combining and utilizing resources in various ways will prove profitable in some instances and useless in others. The firm will begin to recognize the value of these combinations and will develop stylized procedures with which to confront novel stimuli (Nelson and Winter, 1982). Furthermore, the competent firm will develop an ability to reconstitute routines in order to counter their obsolescence. These combinative capabilities (Kogut and Zander, 1992) allow for the destruction of obsolete knowledge and its reconstitution into new and valuable knowledge.

As such, tacit knowledge is acquired through "learning-by-doing" (Stiglitz, 1987) or "learning-by-using" (Rosenberg, 1982) and, therefore, mere observation of firms possessing such knowledge will not lead to its acquisition by knowledge-deficient firms. It is "acquired only experientially and transferred by demonstration, by personal instruction, and by the provision of expert services" (McFetridge, 1995, p. 413, citing Dasgupta and David, 1994). Thus, aspiring imitators, to some degree, must "recreate" history (Arthur, 1988) in order to acquire this knowledge.

Since tacit knowledge cannot be exactly copied by other firms it is effectively rival, at least to unrelated parties, in the sense that the cost of extending provision to one more user is high. Therefore the more tacit the technology, the more likely that it will be transferred within the MNE hierarchy to wholly-owned subsidiaries; whereas the more codified and teachable the technology the more likely that third party routes will be used (Kogut and Zander, 1993). That is, complexity increases the probability of internal transfer.

These conclusions may seen somewhat paradoxical. In the public goods perspective, FDI through wholly-owned subsidiaries (the hierarchy) was perceived to be the MNE's preferred route to prevent dissipation of the potential rents from knowledge production. In the more recent literature, it is the private characteristic of tacit knowledge that is the core competency of the MNE, and it is the difficulty of providing this knowledge to recipients that leads the MNE to choose the hierarchy over the market. So, publicness favoured the hierarchy over the market in the traditional view (to lessen the risk of dissipation of the firm's FSAs through technology spillovers and opportunistic behaviour). More recently, the common view is that tacitness (privateness) is the justification for the hierarchy (internal transfers reduce the costs of learning-by-doing, tacitness keeps the core competence of the MNE from dis-

sipating). We explore the paradox below in our examination of the costs of technology transfer.

Yet, an important limitation on the returns to the MNE from its FSAs derives from the associated costs of transaction which include the costs of search, enforcement, bargaining, and opportunism, as well as provision costs and dissipation costs. These are discussed in more detail below.

3. Multinationals and technology transfer

The technology transfer process involves the acquisition, assimilation, diffusion, and development of technology (Tung, 1994; Caves, 1996). Technology can be transferred through formal market means or informal, nonmarket mechanisms; the latter can be voluntary or involuntary (Kokko, 1992). Demonstration effects, the movement of skilled workers from one firm to another firm, and supplier-buyer linkages are all types of informal mechanisms by which knowledge is diffused. The role of the technology producer can be active or passive in the technology transfer process. For example, trade in finished goods can lead to reverse engineering; in such cases the knowledge generator is a passive actor in the technology diffusion process. On the other hand, joint ventures, licensing arrangements, and other forms of strategic alliances can lead to active participation in technology transfer.

However accomplished, technology transfer involves several types of costs for the producer. Figure 1 outlines four different, but interrelated, costs of technology transfer. The first cost type is the *transfer costs of making a market* in an uncertain world (Casson, 1982). These include costs of search, negotiating a contract, monitoring and enforcing the contract. Internalization theory argues that transfer costs are higher for external transfers than for transfers through the hierarchy (Rugman, 1986).

The second category of costs are the risks and *costs of opportunistic behaviour* by the transacting parties, as each attempts to alter the terms of the bargain in its favour. As uncertainty increases, so does opportunism. Because knowledge is often impacted, both parties are reluctant to reveal too much information for fear of giving away an advantage (Hamel, 1991; Johnson, 1970). In general, technology transfer within the hierarchy should be less subject to such pressures than external transfers.

The third category is *provision costs*; i.e. those identified by Teece (1977), Cantwell (1991), and Kogut and Zander (1993) referring to the costs of providing knowledge or technology to other entities, such as subsidiaries, affiliates, or external organizations. For public technology, these

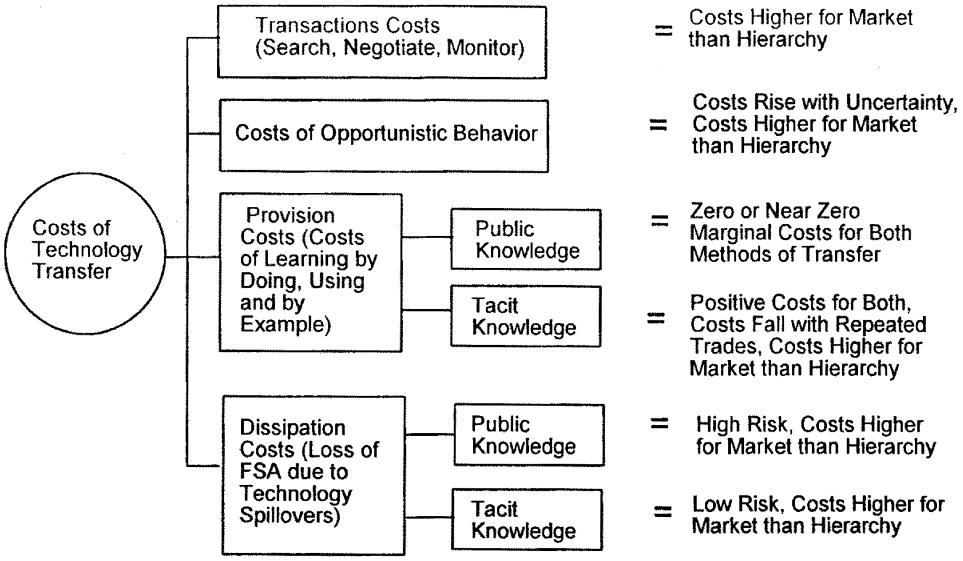

Fig. 1. Market vs. Hierarchy: which method has higher technology transfer costs?

provision costs are approximately zero; whereas for tacit knowledge, provision costs can be substantial. Since provision costs depend on knowledge of routines and fall with repeated trades, one would expect such costs, for tacit knowledge, to be less within the hierarchy than through the market. For pure public goods, provision costs should be near zero for both methods. Note that high provision costs should be seen as a benefit to the MNE if the firm wishes to protect knowledge from diffusion outside the hierarchy. That is, the high costs of learning-by-doing suggests that unintended transfers provide minimum benefit to third parties. On the other hand, if the MNE does want to sell or lease its technology on the private market, high provision costs mean substantial costs must be incurred in terms of codifying knowledge, providing on-site technical experts, and so on.

The last category is *dissipation costs*; i.e. the risk of loss of the MNE's firm-specific advantage. For example, technology spillovers to competing firms can reduce the rents from knowledge production. This risk is highest with public knowledge where the appropriability regime is weak since it is difficult for the technology producer to protect its investment from free riders (Teece, 1987).[5] Dissipation costs imply that technology transfer has quasi-congestion costs in the sense that extending consumption to an additional user reduces the benefits to the original user (i.e. providing benefits to Y means lower returns to X). Dissipation costs are linked with opportunistic costs in that, as uncertainty increases, the risk of opportunism and of dissipation both increase.

The public goods perspective has been particularly concerned with the last of these four types of technology transfer costs, i.e. the dissipation costs associated with knowledge as a public good. Discussions of tacit knowledge as the core competence of the MNE stress mostly the third cost: those of provision (costs of learning-by-doing, -using and, -example) associated with tacit knowledge. Whether the knowledge dynamics of MNEs are affected most by the publicness or the tacitness of knowledge therefore depends on one's view of the size and significance of knowledge spillovers (how tight is the appropriability regime protecting knowledge from dissipation?), and the size and significance of the tacitness of knowledge (how costly is it to disseminate knowledge between firms?). We turn to knowledge spillovers and the appropriability regime below.

4. Multinationals and technology spillovers

Spillovers, or externalities, are one of the most important ways that MNE technology is transferred to host countries. A technology spillover occurs when the activities of one firm lead to improvements in the technology or productivity of another firm such that the first firm cannot capture all the quasi-rents created by its productive activities. Technology spillovers are informal, nonmarket transfers that occur involuntarily.

The nature of technology spillovers

Some of the ways that MNE technology can spill over to host country firms include:

- local firms attempt to copy the MNE's product or process technologies (*the demonstration effect*).
- backward and forward linkages between the MNE and its suppliers and buyers facilitate *learning-by-doing* by the local firms, creating a mechanism that reduces the provision costs of technology transfer.
- *training of local employees* by the MNE provides a more highly skilled labour pool for other firms, and a potential source of new start-up firms, thus creating an external benefit for other firms.
- entry of an MNE generates more competition within an industry so local firms are forced to use existing technology more efficiently or to upgrade their technology in order to remain competitive (what Kokko (1992, p. 25) describes as the *competition effect*).

We briefly review each of these methods below.

The *demonstration effect* occurs as reduced geographic and operational proximity increases information flow among firms and facilitates learning by the incumbent firms. Before a technology is widely known, lack of information about its benefits and costs imply uncertainty and may discourage existing firms from adopting the technology. Technology should spread most easily when the producer and potential user are already

in contact so that linkages already exist. Like the flu bug in the winter, technology diffusion happens easiest when the parties are geographically and operationally proximate. This contagion effect suggests that diffusion should be faster the closer the proximity and the larger the share of the MNE's technology in the local base.

Learning-by-doing occurs as linkages among firms force all firms to (attempt to) adopt common routines, industry norms, acquisitions standards, etc. Such conformity, on the surface, will reduce costs of transaction as exchange is governed by widely shared procedures (and, thus, new procedures do not have to be created for each transaction). However, at a more abstract level, conformity will cause technologically-deficient firms to operate in manners similar to those firms possessing valuable technologies. As such, technologically-deficient firms may be forced to mimic the actions of technologically-superior firms, resulting in experiential learning by the former.

Furthermore, as suggested by Almeida and Kogut (1995), spillovers may occur as technologically-superior firms *train local employees*. Once trained, these employees may be subsequently hired by technologically-inferior firms and, thus, may provide these firms with superior technology. Further, highly-trained local employees may feel compelled to apply their new-found expertise to entrepreneurial ventures which further diffuse the knowledge throughout local markets.

The *competition effect* arises from increased competition occasioned by the entry of the MNE into a host country. Such entry puts pressure on existing firms threatened with loss of market share. Their response may be to more efficiently use existing technology or to upgrade, either following the entrant or pursuing their own technology track/paradigm.[6]

It should be noted that technology spillovers are an implicit cost to the firm since they represent benefits which are not fully appropriated by the producing firm; benefits that could have been earned if the regime of appropriability had been more effective. Thus the total productive volume of technology by the MNE may be reduced by the existence of technology spillovers (Caves, 1996, p. 181). That is, recognizing the potential for incomplete appropriation, MNEs may under invest in technology generation or may erect such strict barriers to diffusion that even internal transfer of technology is hampered. In addition, technology spillovers can provide *recipients* with the ability to compete directly against the MNE, thus providing further impetus to reduce technology production.[7]

Technology spillovers and the appropriability regime

How high is the risk of technology spillovers? Figure 2 shows that the risk varies inversely with the tightness of the appropriability regime protecting the firm's technology assets; that is, how well the property rights regime protects asset holders.

First, the simplest, most basic method of deterring spillovers is through the granting of property rights to the technology (e.g. patents, copyrights).

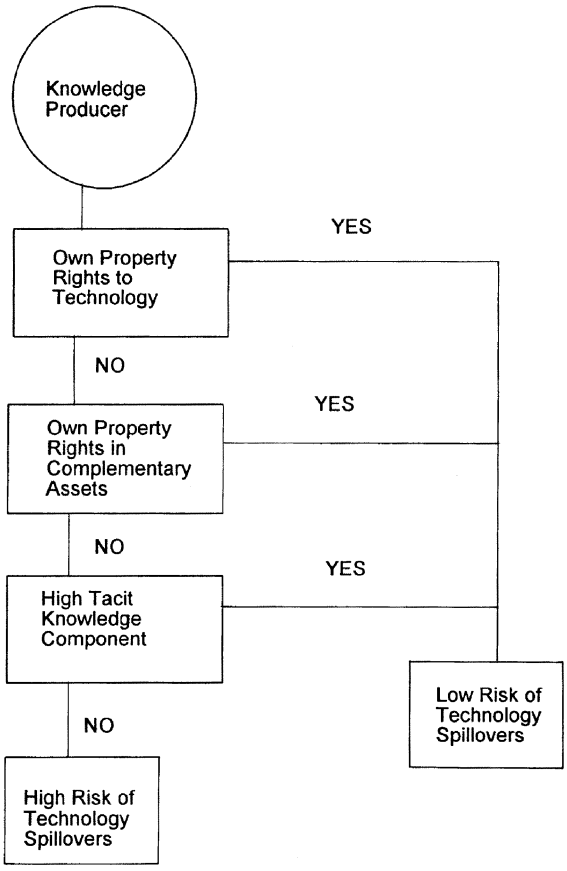

Fig. 2. How high is the risk of technology spillovers?

This, in theory, allows the producing firm to be compensated for its innovative efforts and expense before legal diffusion of the technology becomes widespread. Second, even without ownership of the technology, expropriation by competitors may be prevented if the producing firm owns complementary and/or co-specialized assets that are necessary to realize the full value of the diffused technology. In this case, risk of dissipation is attenuated if, for example, the cost faced by imitators to build such assets is exorbitant (Teece, 1987). Third, operating technologies employed by the firm may be partially composed of a tacit element. Firm-specific routines (Nelson and Winter, 1982) and combinative capabilities (Kogut and Zander, 1992) may guide the process through which technologies are exploited by the possessing firm. Thus, even if a portion of the firm's technology is derived by relatively codifiable knowledge, the ability of other firms to acquire a firm's entire portfolio of knowledge will be limited by codifiability constraints. If the tacit component of knowledge is high, the MNE can still maintain a tight appropriability regime and deter spillovers.

The implication of Figure 2 is that the tightness of the appropriability regime, whether derived from property rights or tacitness, is another key to the success and growth of the multinational enterprise. It is the proprietary assets that create value for the firm, and these assets "may possess either the limitless capacities of public goods (the strict intangibles) or the flexible capacities of the firm's repertory of routines" (Caves, 1996, p. 4).

One *ex post* measure of the tightness of the appropriability regime is the existence and location of technology spillovers. Evidence on technology spillovers has come from a variety of sources (Caves, 1996; Dunning, 1993; Kokko, 1992). Some authors have looked at the increase in total factor productivity in the host country after the entry of foreign multinationals, focussing on the link between R&D expenditures and economic growth. Others have looked for new linkages, backward and forward, between the MNE and host country firms. Still others have investigated the impact on efficiency of firms in an industry as a result of new entry.[8] Difficulties in measuring technology spillovers may lead to serious under- or over-estimation of their size. Hence the interest in the work of Jaffe et al. (1993) and Almeida and Kogut (1995), who have used patent data to determine the size and the location of technology spillovers, to which we now turn.

The localization of technology spillovers

Technology spillovers can be measured using patent data. A patent is a "property right in the commercial use of a device" (Jaffe et al., 1993, p. 580). Patent statistics have often been used to proxy for technology because the statistics are readily available over long periods and in great detail. They also capture knowledge activities in and outside of R&D departments (Patel and Pavitt, 1991).

Patents represent knowledge "which can be articulated, codified, and legally enforceable in their protection" (Almeida and Kogut, 1995, p. 4). They have a double-barrelled effect: (i) they convey a temporary monopoly on the patent holder and (ii) they disclose information to the general public about the technology in codified form. That is, patents benefit the patent holder because they convey a property right on which the firm can earn rents; the scope of the patent is defined in the description of the patented product or process.

However, patent protection is imperfect (Levin et al., 1987) and the process of obtaining a patent discloses information that can be used to imitate the patented technology either illegally or via carefully considered substitute, but similar, processes. Successful imitation dissipates the rents the original technology producer can earn from its investment and thus reduces the value of the patent to the original firm. The first impact of a patent therefore reduces knowledge spillovers (by defining the boundaries of the innovation), while the second increases spillovers (by providing information to competitors).

Almeida and Kogut (1995, p. 1) argue that "ideas, because they have no material content, should be the least spatially bounded of all economic activities." Accordingly, patents provide a "paper trail" for the flow of ideas from one innovator to another. Citations in a patent are used to delimit the scope of the property right conveyed by the patent. A citation of X by Y means that Y builds upon X; therefore the more *citations* within a firm's patent filing, the smaller will be the scope of the monopoly held by the patent holder.

Therefore, the scope of that firm's invention will be reduced accordingly. A citation of X by Y and then of Y by Z provides a paper trail for the technology diffusion process.

The use of patent citations to examine technology spillovers was first suggested by Jaffe (1989) and Jaffe et al. (1993) who examined the location of university and large firm patents in the United States in 1975 and 1980. Acs, Audretsch and Feldman (1994) looked at corporate patenting by U.S. states and found evidence of geographic concentration.

Almeida and Kogut (1995) expand on this work by focussing on the geographic spillovers from patenting in the semiconductor industry, examining the role played by migrating engineers with patents "under their belts", and the role of startups in technology spillovers. The authors use patent data on semiconductor inventions to address the question: Where do knowledge spillovers go? Do they go to nearby firms, firms in the same country or do they "go global"?

The public finance literature on local public goods suggests that spillovers are geographically bounded (i.e., the greater the distance from the original activity, the smaller the positive or negative externality (Eden and McMillan, 1991)). If knowledge has the characteristics of a local public good (as in the publicness perspective we outlined above), the general presumption would be that knowledge spills over to other agents in the same region, but not outside of that region.[9] This could happen for a number of reasons. In some cases, local environmental conditions or natural resource endowments will catalyse the development of various industries within a region (Porter, 1992). In other instances, a single firm will spin off companies or otherwise provide a supply of employees to start-up companies in the same region (Moore, 1986).

In either case, given a common historical background, most if not all firms within that region will embark upon a common technological trajectory. As these firms proliferate, related local industries or institutions (e.g. universities) supplying these firms with production factors will also flourish, thereby reinforcing the movement along the localized technological trajectory (Acs, Audretsch, and Feldman, 1994; Porter, 1992).

Informal communication networks of managers/scientists may also arise as the geographic proximity of firms is relatively close, thus providing a cross-fertilization of ideas among the firms in a specific region (Rosenberg, 1982; von Hippel, 1988). Cross-fertilization may be further enhanced as managers/scientists move from firm to firm within a region (Almeida and Kogut, 1995). Thus, as firms within a region possess similar endowments of physical and human capital, they will confront similar opportunities to learn, as well as develop similar proficiencies in the ability to "learn to learn" (Stiglitz, 1987). Knowledge, thus, may become localized as firms within a region become proficient at absorbing knowledge diffused by cohorts.

Two other points with regard to the localization of knowledge are worth noting. First, Almeida and Kogut's (1995) results suggest that, even if certain knowledge is manifest in a relatively mobile form (e.g., information contained in patent filings), complementary assets (e.g., close proximity to university research labs and personnel) may not be as mobile, thus providing a further geographical restriction of knowledge diffusion. Second, and equally as important, is the notion that it may be less costly for firms to adopt technologies similar to those of its geographic neighbours. That is, if the firm is "near others technologically, it will receive benefits – in the form of improved technology and improved learning capabilities – which it would not receive if it decided to strike out on its own" (Stiglitz, 1987, p. 132). In others words, localization may also be a *consequence* of the conscious effort on the part of a firm's managers to avail themselves of spillover opportunities.

Hence, when considering the MNE, a critical issue arises: Where should R&D be undertaken by the MNE? In terms of public policy, if the MNE conducts R&D outside of the home country, that country may lose most of the benefits of spillovers. Accordingly, such spillovers are a major reason why host countries want to attract MNEs: to access these potential externality gains (Cantwell, 1991; The Economist, 1995; Harris, 1991).[10]

So far in this paper, we have concentrated on the role of large multinationals in the production, diffusion and spillover of technology. What do we know about the differences between large MNEs

and small and medium sized enterprises (SMEs)[11] in technology production? Are there differences between large and small firms in terms of their technology FSAs, technology transfer, and technology spillovers? We address these issues below.

5. Technology production: comparing SMEs and MNEs

An early comparison between large and small multinationals in terms of technology production was conducted by Giddy and Young (1982) in their work on nonconventional multinationals; that is small MNEs and MNEs from poor or small countries. Giddy and Young found that nonconventional MNEs were less likely to be technology innovators and more likely to be fast followers or imitators. They were more likely to use joint ventures and licensing rather than wholly-owned subsidiaries to enter host countries. Oman (1984) reached similar conclusions in his work on new forms of international investment. These authors cited financial constraints and lack of "cutting edge" proprietary technology as reasons why nonconventional MNEs would be more likely to use alternative contractual forms for penetrating foreign markets.

More recent work shows that technological innovations emerge from both small and large firms. However, as Acs and Audretsch (1988) found, differences exist in the level of innovative activity between large and small firms as industry conditions change. Acs and Audretsch conclude that, similar to Winter's (1984) predictions, different economic and technological regimes exist across industries such that large firms account for most of the innovative activity in industries in which R&D is especially salient. At the same time, small firms account for a more significant proportion of innovative activity in industries in which small firms are few in number and in which skilled labour plays an important role. The authors later conclude that:

> . . . most industries exhibit decreasing returns to scale with respect to the output of innovations. However, this relationship is apparently sensitive to the technological environment. In low-technology industries, there is at some evidence of increasing returns. (Audretsch and Acs, 1991, p. 744)

This reinforces the notion that small and large firms are engaged in innovative activity to different degrees depending on the technological regime prevailing in a given industry.

Almeida and Kogut (1996) compare the innovative patenting activities of small and large firms in the semiconductor industry. The authors find that small firms tend to innovate in less crowded areas while larger firms dominate patenting in well established areas. Part of the reason is that small firms tend to be start ups, receiving funding to explore new fields. In addition, the research activities of small firms tend to be more geographically localized. The authors argue that this localization is because start-up firms are more closely tied into regional networks than are large firms, and that this is particularly true for semiconductor firms in the Silicon Valley. This may imply a "dense national small firm network, with larger firms bridging nations" (Almeida and Kogut, 1996, p. 30). The authors conclude that small firms innovate in order to benefit from their own research and their local innovatory network.

To the extent that organizations innovate, the opportunity arises for them to transfer that technology when and where appropriate. The simple transfer of technology (the acquisition element of the transfer process), however, is the perhaps the least problematic aspect of technology transfer (Tung, 1994). With regard to the propensity to transfer technology, SMEs and MNEs both have demonstrated a need to transfer technologies to foreign affiliates and other partners.

Although both SMEs and MNEs primarily transfer technology from a parent firm to a foreign affiliate, i.e. through the hierarchy, SMEs are in many cases more likely than MNEs to engage in joint ventures and other types of alliances (Gomes-Casseres, 1995). Thus, it is more likely that SMEs will find it necessary to combine resources and efforts with alliance partners (in terms of licensing arrangements, equity ventures, non-equity ventures, etc.) in order to compete effectively (Teece, 1992). This increases the likelihood that technology transfer by SMEs will cross organizational boundaries, increasing the complexity and risk of the transfer process.

Buckley (1995) has examined the technologies likely to be transferred by SMEs and has determined that three types are prevalent. Specifically, he has identified small scale technologies, labour

intensive technologies, and specialized high-technology know-how as probable candidates for transfer by SMEs. While it seems likely that small scale technologies and labour intensive technologies would be internalized through parent-to-affiliate transfers, alliances may allow SMEs to take advantage of high-technology know-how. Through alliances, SMEs may seek to reduce the cost of know-how exploitation by allowing partners to perform non-core, yet capital intensive, functions such as marketing, distribution, and production (Buckley, 1995; Gomes-Casseres, 1995).

As noted earlier, the transfer (or, conversely, acquisition) of technology is relatively straightforward. However, other aspects of the technology transfer process, such as assimilation, diffusion, and development, are more complex and less assured of success (Tung, 1994). Wherever technology is transferred across borders, the likelihood of successful assimilation and utilization is at risk depending on the economic, socio-cultural, and organizational differences between the transferring and receiving firms (Tung, 1994). Furthermore, Kogut and Zander (1993), Teece (1977), and Cantwell (1991) among others, have shown that the transfer of knowledge across borders is increasing in difficulty as the tacitness of that knowledge increases. As such, certain technologies composed of a tacit component, such as organizational or managerial processes, may be exceedingly difficult to transfer across national borders.

The above factors can be applied to the discussion of differences between SMEs and MNEs. The effect of the complexity of technology assimilation and diffusion (not to mention development) on SMEs is not entirely obvious. First, it must be noted that SMEs, due to the relatively small size of their managerial population, are likely to lack the managerial resources of which MNEs can avail themselves. SMEs are less likely to use formalized methods of transfer such as written instructions, sending technical experts abroad or providing formal training. The major method of technology transfer is on-the-job training and the supply of machinery and parts, according to Buckley (this volume).

That being the case, SMEs are also less likely to be able to properly manage the technology transfer process when problems occur. These problems may be the result of differences in economic, socio-cultural, or organizational environments in the case of technology transfer to alliance partners (Tung, 1994). In the case of transfers to foreign affiliates, however, difficulties may still arise due to the tacit nature of the technology being transferred, especially where high-technology know-how is involved (as in the case of biotechnology and semiconductor firms) because of the managerial resources needed to successfully manage the process.

Furthermore, SMEs have significantly less financial resources available to them than do MNEs, thus making it more difficult for SMEs to devote specific personnel and/or funding to aiding the transfer process. As difficulties arise in assimilating and understanding the proper usage of transferred technologies, SMEs will have difficulty alleviating the concerns and addressing the assimilation deficiencies of foreign affiliates and/or alliance partners (Tung, 1994).

In terms of the costs of technology transfer, as outlined in Figure 1, our analysis suggests that SMEs may face higher transactions costs than large MNEs. Although SMEs, due to their relative size, benefit from reduced bureaucratic costs, they also have fewer resources to devote to search, negotiation, monitoring and enforcement efforts. They may also be more subject to opportunistic behaviour on the part of suppliers and buyers due to their smaller size and corresponding inability to retaliate. Being a small technology producer may imply lower costs of transmitting tacit knowledge within the enterprise as a whole; on the other hand, the costs of teaching and learning are more expensive for SMEs since they do not have “deep pockets”.

Lastly, SMEs may be less likely to have a tight appropriability regime protecting their knowledge-based FSAs (e.g. patents are an expensive and time-consuming process, as well as being geographically bounded) and therefore may face higher risks of dissipation and its attendant costs. As Figure 2 suggests, SMEs may be less likely to own property rights to their technology assets, or to own complementary assets such as distribution networks.

In addition, Acs, Audretsch and Feldman (1994) have suggested that large firm managers,

frustrated by bureaucratization, may migrate to (or create) smaller firms in search of a less hierarchical organizational environment in which to utilize their skills. This may provide one mechanism by which small firms avail themselves of spillovers. Furthermore, spillovers to small firms seem to be largely dependent on university research. Thus, even if larger firms are successful in curtailing leakage of proprietary knowledge, localization may still proceed via university and small firm contacts.

Consideration of technology *consumption* suggests that technology spillover opportunities may be especially valuable to technology transferees that are small firms. Limited resources (e.g., human and financial capital) may restrict the scope of small firms' research efforts in comparison to their larger counterparts. And, due to these restrictions, knowledge deficiencies may result. Spillovers may attenuate these effects as small firms acquire knowledge without the attendant acquisition costs. On the other hand, SMEs are less likely than MNEs to engage in FDI, alliances, or technology transfers in developing countries (Buckley, 1995). This eliminates a key source of complexity in technology transfer processes (Tung, 1994). Thus, it is not entirely clear that SMEs will have a more difficult time in successfully completing all phases of the technology transfer process.

In summary, small firms face additional financial constraints that raise the costs of technology production and transfer, relative to large multinationals. Thus, given the relative constraints facing SMEs regarding managerial and financial resources, these firms may face a higher failure rate in transfers of technology than will MNEs. Because of the probable relative gains to technology transfer accruing to SMEs, and the entrepreneurial nature of SMEs and their owners, the risk involved is simply a cost of doing business as a small, internationally-oriented organization.

As methods to overcome the liabilities of their smallness, SMEs tend to use alliances and joint ventures rather than wholly-owned subsidiaries as methods of entry into foreign markets, to focus on niche as opposed to commodity markets, and to use less formal methods of technology transfer. In the most successful cases, SMEs can be 'mini-nationals' in global niche markets. As technology producers, the competitive advantage of mini-nationals comes not from size and deep pockets but from being lean, focussed and flexible; that is, from following the rules: "Do what you know how to do. Do it right. And do it everywhere." (Business Week, 1993, p. 67).

6. Conclusions

Multinational enterprises are the major global producers and disseminators of technology. The core competence of MNEs rests on their proprietary assets, the strength of which depends on the tightness of the appropriability regime protecting these assets. A tight appropriability regime can come from patents protecting public knowledge from dissipation through knowledge spillovers and opportunistic behaviour, or from a high tacit component to the MNE's knowledge assets.

The MNE's mode of entry into foreign markets will depend partly on the relative knowledge transfer costs of using the external market versus the hierarchy. These costs include costs of making transactions, the risks of opportunism and dissipation of FSAs, and the costs of disseminating tacit knowledge. Technology spillovers tend to be localized because, even if the public component is high, technology has a tacit component that reduces the spillover range.

For small and medium sized enterprises, the costs of technology production and transfer are high. As a result, SMEs tend to use less conventional methods: they rely more on joint ventures and alliances, they use less formal methods of technology transfer, and they focus on niche markets. The most successful SMEs, due to their competitive advantage in flexibility, can become mini-nationals. This suggests that technology production need not always be the *sina qua non* of large multinationals; small and medium sized enterprises can also become active technology producers in the global economy.

Notes

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SMEs, and two anonymous referees for their comments on the paper.

[1] See, for example, Chapter 6, "Transnational Corporations, Technology and Growth" in *World Investment Report 1992*.

[2] We consider technology and knowledge to be the same in this paper. Following Dunning (1988, p. 287) we define technology as the "output of technological and organizational capacity, which determines the way (or ways) in which tangible and intangible resources may be physically converted into intermediate and finished goods and services".

[3] Jointness means that once a good is produced the marginal cost of extending provision to an additional consumer is zero or near zero. That is, the use by one agent has no impact on the amount available for use by others. The opposite of jointness is rivalness; i.e. if increasing the number of consumers from N to $N + 1$ reduces my share from $1/N$ to $1/(N+1)$ the good is rival; if my share remains $1/N$ as N rises, the good is joint. Jointness fails, for example, if increasing the number of consumers creates congestion costs. Note that even if the marginal cost of provision is zero, the price will be nonzero since costs of production must be covered if the good is to be produced at all. The key is that, once the good is produced, the marginal cost of adding an additional consumer is zero (Eden and McMillan, 1991).

[4] Nonexcludability means that the price system cannot be used to ration consumption of the good. Price exclusion may not be feasible for institutional reasons (such as a lack of assigned property rights) or for technological reasons (e.g. national defence) or because consumer preferences cannot be ascertained due to preference revelation problems. Where exclusion is not possible, self interested consumers are likely to free ride, leading to under provision of the good or service (Eden and McMillan, 1991).

[5] Johnson (1970) even suggests that free riding (underpayment for technology transfers) might be acceptable, on equity grounds, for developing countries that have little chance of becoming home countries for MNEs.

[6] This is the "fresh winds of competition" argument often used by Canadian economists as one of the arguments in favour of Canada-U.S. free trade (Lipsey, Schwanen and Wonnacott, 1995).

[7] This latter effect is akin to the congestion effects of local public goods, where the addition of more consumers causes congestion that reduces the benefit to the existing agents (Eden and McMillan, 1991).

[8] For a thorough literature review on the theory and empirical work on technology spillovers, together with some new estimates, see Kokko (1992).

[9] However, the reverse view is suggested by the theory of epistemic communities, as developed in the field of international political economy (Haas, 1989). An epistemic community is a group of like minded scholars that share the same beliefs and goals (for example, the "green" coalition of environmental activists, ecology experts and university scientists); such communities often span several countries. Mobility of ideas may spread more easily and quickly within an international epistemic community than within a country.

[10] For a more thorough discussion of the locality considerations surrounding R&D, see the work of Pearce (1989) and Casson (1991).

[11] Note that the definition of a small and medium sized enterprise must be made relative to the size of the market. A small firm selling only in a niche market may hold the largest share of that market and therefore be a "large" firm. Our definition of SMEs assumes that the firms are small relative to the size of the market.

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