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The paradox of technological capabilities: a study of knowledge sourcing from host countries of overseas R&D operations

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Abstract
We investigate the factors that influence the extent to which a multinational corporation's headquarters (MNC-HQ) sources knowledge from the host countries of its R&D labs. We propose that the technological capabilities held by MNC-HQs present a paradox. On the one hand, they enhance MNC-HQs' learning capabilities. On the other hand, they reduce MNC-HQs' motivations to outsource knowledge from host countries. We also argue that it is important to consider both relative and absolute levels of technological capabilities, because relative levels can influence MNC-HQs' motivations to source knowledge from host countries. Statistical findings generally support our arguments.
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INTRODUCTION

Traditional theories of foreign direct investment (FDI) suggest that multinational corporations (MNCs) undertake FDI in order to transfer and exploit their home-country-based knowledge to foreign countries (Caves, 1971; Hymer, 1960). In recent decades, however, MNCs have set up R&D labs overseas to acquire and develop knowledge complementary to that derived in their home-country operations (Asakawa, 2001; Kuemmerle, 1999; Shan & Song, 1997). Traditionally, most technology-seeking FDIs occurred in developed countries such as the USA, Europe, and Japan by MNCs originating from these advanced countries. However, recently, improvements in the technological capabilities of countries that had not historically been among the leading innovators – for example, Taiwan, South Korea – have accelerated the increase in technology-seeking FDIs (Furman, Porter, & Stern, 2002).

Although several studies investigate MNCs' knowledge-sourcing behaviors, few examine how MNCs' overseas R&D influences the R&D they do in their home countries, which is where they concentrate this activity. Penner-Hahn and Shaver (2005) contend that, despite the burgeoning literature that enjoins firms to internationalize their R&D in order to access new technologies, we know little about the conditions that induce MNCs to do so. In addition, recent research on knowledge-seeking FDIs has largely "missed the opportunity for theoretical advancement that might

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arise from drawing upon more general theories of innovation and technological progress in organizations'' (Frost, 2001: 101). In this paper we examine how the technological capabilities of MNC headquarters (MNC-HQ) affect the level of knowledge that they source from the host countries of their overseas R&D labs. Drawing on the absorptive capacity view and evolutionary economics, we advance theory about knowledge-seeking FDIs by developing a framework of the ''paradox of technological capabilities''. On the one hand, the technological capabilities of MNC-HQs contribute to their absorptive capacities to source knowledge from host countries. On the other hand, MNC-HQs with strong technological capabilities are likely to have established their own technological trajectories, which constrain their search for new capabilities and make them less motivated to source new knowledge from host countries (Nelson & Winter, 1982; Stuart & Podolny, 1996).

We also propose that not only absolute but also relative levels of technological capabilities influence MNC-HQs' motivations to outsource knowledge from host countries. We examine the effects of relative levels of technological capabilities in terms of:

(1) the ratio of MNC-HQs' technological capabilities to those of their home countries;
(2) the ratio of home countries' to host countries' technological capabilities; and
(3) similarities in technological profiles between MNC-HQs and host countries.

Specifically, we propose that when MNCs are technological leaders in their home countries, they are more motivated to learn from host countries because they have relatively little to learn in their home countries. We also propose that MNC-HQs are more likely to outsource knowledge from host countries with technological capabilities that are strong relative to those of their home countries. Finally, we argue that an MNC-HQ's level of knowledge outsourcing from host countries will first increase and then decrease as the distance between the technological profile of the company and that of its host country increases.

We investigate knowledge sourcing from host countries of overseas R&D labs in the global semiconductor industry. We use US patent data to trace knowledge flows from host countries to MNCs' R&D labs in their home countries. We then employ negative binomial regressions to investigate the factors influencing the level of knowledge sourced from host countries. Our results support our arguments regarding both the paradox of technological capability and the influence of relative capabilities.

LITERATURE REVIEW AND THEORY

Advances in Global R&D Activities and an Emerging View of MNCs

Recently, both the extent to which MNCs perform R&D outside their home countries and the types of foreign R&D have changed considerably. Kuemmerle (1999) has documented significant increases in the R&D that MNCs do abroad. Further, although MNCs originally focused most of their foreign R&D on adapting technologies they had developed at home to foreign production conditions, Dunning (1993) and Kuemmerle (1999) found that MNCs have recently accelerated their efforts to acquire and develop new technologies overseas. Leading MNCs have now established vast global networks that access technologies from various locations (Bartlett & Ghoshal, 1989; Hedlund, 1986).

Scholars have responded to MNCs' globalization of R&D by focusing more extensively on how MNCs use FDI not only to ''push'' their existing advantages in exploiting foreign markets but also to ''pull'' new resources and capabilities from centers of innovation by acquiring or learning about complementary technologies (Almeida, Song, & Grant, 2002; Shan & Song, 1997; Singh, 2004). When knowledge is sticky and remains confined within narrow geographical boundaries (Jaffe, Trajtenberg, & Henderson, 1991), a manufacturing or R&D location serves as an important source of competitive advantage (Almeida, 1996). Firms located in innovative regions such as Silicon Valley have greater access to new technological knowledge than do their spatially distant counterparts. MNCs can develop competitive advantages by locating in overseas technological centers of excellence that offer differentiated streams of new knowledge, so long as they can learn to identify, transfer, and integrate the knowledge they derive in host countries throughout their operations (Almeida et al., 2002).[1]

Using industry-level data, empirical research supports the arguments that MNCs employ FDI to source knowledge. For example, Cantwell (1989) found that MNCs are especially attracted to centers of innovation as a means of broadening their knowledge bases. He argues that the popularity of such centers is attributable to persistent country-level differences in technological capabilities.

At the firm level, Almeida (1996) found that foreign MNCs' US subsidiaries use knowledge derived from the regions where these subsidiaries are located significantly more than similar US firms from the same region do. He suggests that MNCs in the semiconductor industry use FDI to access local information channels and source location-specific knowledge. Similarly, Shan and Song (1997) found that in the biotechnology industry foreign MNCs invest in American biotechnology firms that patent frequently, thus sourcing country-specific, firm-embodied technological advantages. Almeida et al. (2002) showed empirically that, in the semiconductor industry, internal mechanisms within MNCs are more effective than are markets and alliances for transferring technology across borders.

The Paradox of MNCs' Technological Capabilities

An increasing number of MNCs set up R&D laboratories in foreign countries to develop links to local scientific and technical communities in order to source complementary knowledge (Florida, 1997). Yet few studies have shown what factors affect the extent to which MNC-HQs source knowledge from host countries. In this paper, we focus on the paradoxical effects of MNC-HQs' technological capabilities. The technological capabilities of MNC-HQs affect the likelihood of their knowledge outsourcing from host countries both positively and negatively. On the one hand, the absorptive capacity aspects of technological capabilities influence MNC-HQs' knowledge sourcing from host countries positively. On the other hand, the strong technological capabilities of MNC-HQs may reduce their motivations to learn from others, thereby affecting the MNC-HQs' knowledge sourcing from host countries negatively. Thus we examine both positive absorptive capacity and negative motivational aspects of MNC-HQs' technological capabilities.

Absolute Technological Capabilities versus Relative Technological Capabilities

In assessing how MNC-HQs' technological capabilities influence their knowledge sourcing, it is important to consider both relative and absolute levels of technological capabilities. Most studies of international R&D focus exclusively on absolute levels of technological capabilities held by firms, home countries, and host countries (Cantwell & Janne, 1999; Florida, 1997; Kuemmerle, 1999). Yet recent work contends that relative levels are also important (Darr & Kurtzberg, 2000; Lane & Lubatkin, 1998; Mitchell, Baum, Banaszak-Holl, Berta, & Bowman, 2000). For example, Lane and Lubatkin (1998) suggest that a firm's ability to learn depends on its relative absorptive capacity, which represents the similarity between the teaching unit and the learning unit. Since learning occurs in a dyadic relationship between the learning unit and the teaching unit, knowledge-sourcing behaviors need to account for both the absolute and the relative characteristics of these units.

Let us first describe how absolute levels of technological capabilities can influence knowledge outsourcing from host countries. An MNC can enhance its absorptive capacity by having strong technological capabilities (Cohen & Levinthal, 1990) and use this capacity to source more knowledge from others. However, these capabilities may reduce the MNC's motivation to learn from others, partly because of routine-constrained choices (Nelson & Winter, 1982) and partly because of the diminished incentives that firms have to outsource knowledge.[2] For example, drawing on evolutionary economics, Song, Almeida, and Wu (2003) showed that firms with well-established technological paths are less likely to source knowledge from newly scouted engineers than firms with under-established technological paths. Similarly, Chung and Alcacer (2002) and Flyer and Shaver (2003) found that MNCs with absolute technological advantages are less likely to establish advanced R&D facilities overseas. Mitchell et al. (2000) also argue that, although nursing home chains with strong capabilities may have more opportunities for knowledge transfer across units, a nursing home unit with a relatively high capability level is less likely to bring in knowledge from other units in its chain.

As we emphasized above, relative levels of technological capabilities also affect knowledge outsourcing from host countries paradoxically. In this paper, we examine relative aspects of MNC-HQs' technological capabilities in terms of:

(1) the technological capabilities of MNC-HQs relative to those of their home countries;
(2) the relative differences between the home and the host country; and
(3) the similarity/dissimilarity between an MNC-HQ and a host country in technological profiles.

By focusing on relative capabilities, we are better able to capture the motivational factors underlying knowledge sourcing and transfer that are ignored when only absolute levels of technological capabilities are examined. The first two types of relative capabilities in the above classification especially influence the motivational aspects of technological capabilities. However, as we elaborate below in the hypothesis section, the third type of relative capabilities – technological distances between an MNC-HQ and a host country – include both positive absorptive capacity aspects and negative motivational aspects for knowledge outsourcing from host countries.

In this paper, we analyze the paradox of technological capabilities by examining empirically how the technological capabilities – both absolute and relative levels – of an MNC-HQ influence its knowledge sourcing from host countries where its R&D labs are located.

Hypotheses

Technological capabilities of MNC-HQs in home countries. MNC-HQs' technological capabilities are important in determining their propensity to source knowledge from overseas. To identify, acquire, and assimilate valuable external knowledge, especially tacit knowledge, a firm must possess considerable absorptive capacity (Cohen & Levinthal, 1990) in related technological areas. Cumulative experience with a technology often determines the recipient's absorptive capacity to acquire such tacit knowledge. Therefore a firm's prior knowledge base and cumulative investment in learning capabilities affect its absorptive capacity. Firms seek to acquire knowledge externally when there is a significant knowledge gap between them and industry leaders. Yet firms that develop substantial cumulative experience and knowledge bases are better positioned to acquire target technologies (Leonard-Barton, 1995).

The absorptive capacity view suggests that MNC-HQs with strong technological capabilities are superior in assimilating and extending knowledge sourced from overseas R&D labs. Cumulative experiences and knowledge enable firms to assimilate external knowledge more efficiently. Therefore firms with stronger knowledge bases can absorb external knowledge better, with less effort, than those with weaker knowledge bases. Penner-Hahn and Shaver's (2005) analysis of international R&D expansions by Japanese pharmaceutical firms found, for instance, that firms benefit from international R&D when they possess existing technological capabilities in underlying technologies. The absorptive capacity view implies that the level of productivity of knowledge sourcing from host countries should be higher in MNC-HQs with strong technological capabilities than it is in MNC-HQs with weak technological capabilities.

Yet above a certain threshold level of technological capabilities, MNC-HQs may be less willing to source new or complementary knowledge from host countries because they may have already established distinct technological paths or routines. A firm's innovative activities are often cumulative, path-dependent processes (Dosi, 1982), which constrain its future search behavior for new technologies and make it more likely to pursue R&D along its existing trajectories. Especially in the international setting, an MNC-HQ may have additional difficulty associated with creating new routines to incorporate geographically dispersed knowledge. Thus, in MNCs with established trajectories based on strong technological capabilities, learning or innovative searching tends to be local – in other words, home country based, cumulative, and internal (Stuart & Podolny, 1996). Such MNC-HQs may be less motivated to absorb and utilize new knowledge from host countries where they set up R&D labs.

Hence, considering these paradoxical aspects of technological capabilities, we hypothesize an inverted U-shaped relationship between the technological capabilities of an MNC-HQ and the level of knowledge sourcing from the host country:

> **Hypothesis 1**: An inverted-U relationship is predicted between an MNC-HQ's technological capabilities and the degree of knowledge sourcing from a host country: that is, an MNC-HQ with moderate levels of technological capabilities will source knowledge from the host country more than does an MNC-HQ with lower or higher levels of technological capabilities.

Relative technological capabilities of MNC-HQs to their home countries. MNCs that are technological leaders in their home countries may be more motivated to outsource knowledge from host countries (Florida, 1997; Kuemmerle, 1999) because they may not have much left to learn within their home countries. In small countries, the level of technological capabilities in an industry frequently depends on only one or two firms. For example, Philips was a dominant innovator in the electrical equipment industry in the Netherlands (Cantwell & Janne, 1999). In such cases, these firms may be highly motivated to search for technological opportunities outside their home countries. On the other hand, if an MNC is not a technological leader in its home country, or if there are many other innovators in its home country, it may find that searching for technological opportunities in its home country is more efficient than doing so in foreign countries would be. Thus we argue that MNC-HQs with strong technological capabilities relative to those of their home countries are more motivated to outsource knowledge. Hence we propose:

> **Hypothesis 2**: The more dominant an MNC-HQ's technological capability is relative to the stock of capabilities in its home country, the more likely it is to source knowledge from host countries.

Relative technological capabilities of home countries to host countries. Kuemmerle (1999) found that when a host country spends more on R&D than a home country does, MNCs tend to source knowledge from the host country more actively by setting up "home-base augmenting" labs. Frost (2001) showed that overseas R&D labs are more likely to draw on knowledge from host countries in technical fields in which host countries have technological advantages. Thus we propose that when a host country has stronger technological capabilities than a home country does, an MNC-HQ is more motivated to outsource knowledge from the host country because the technological trajectories in the home country are less rigid. In addition, relative to the technologically strong host country, the home country has less knowledge for the MNC-HQ to source from. Hence we hypothesize:

> **Hypothesis 3**: An MNC-HQ is more likely to source knowledge from a host country when the host country has stronger technological capabilities than its home country does.

Similarities in technological profiles between MNC-HQs and host countries. The technological distance between an MNC-HQ and its host country may also influence the level of knowledge sourcing from the host country. Lane and Lubatkin (1998), for instance, showed that firms with greater technological overlap have greater relative absorptive capacity and hence are more likely to learn from each other. In a study of the effects of the similarity between tasks on the transfer of knowledge among fast food stores, Darr and Kurtzberg (2000) showed that similarities between stores' strategies and tasks positively affected transfer of knowledge among the stores. In our research setting, given that the technological capabilities of an MNC-HQ can enhance its absorptive capacity, MNC-HQs with technological profiles similar to those of host countries will face less difficulty in learning from the host countries than do MNC-HQs with technological profiles dissimilar from those of the host countries.

Yet it is possible that, when units are too similar, there is little these units can learn from each other, thereby lowering economic incentives to outsource knowledge (Hansen, 1999; Mowery, Oxley, & Silverman, 1998). Thus there may be an optimal technological distance between the MNC-HQ and the host country that influences both the motivation to learn (higher when they are technologically distant) and the ability to learn (higher when they are technologically close). On the one hand, an MNC-HQ with technological profiles highly dissimilar from those of a host country will source knowledge from the host country to a lesser degree because the MNC's capacity to absorb this knowledge would be weak. On the other hand, an MNC-HQ with technological profiles highly similar to those of the host country will source knowledge less as well, because it has little to learn from the host country. Therefore we hypothesize as follows:

> **Hypothesis 4**: An MNC-HQ with technological profiles moderately different from those of a host country is more likely to source knowledge from the host country than do MNC-HQs with technological profiles highly similar or dissimilar to those of host countries.

In sum, the degree of MNC-HQs' outsourcing knowledge from host countries depends on both their absorptive capacities and their motivations to outsource knowledge. On the one hand, an MNC-HQ's technological capabilities enhance its ability to learn and absorb knowledge from host countries, and are thus positively related to the extent to which the MNC-HQ outsources knowledge. On the other hand, both absolute and relative levels of technological capabilities influence the MNC-HQ's motivations to source knowledge from host countries.

METHOD

Data

We use patent data from the global semiconductor industry to test our hypotheses. Over the last decade, patents have become increasingly popular indicators of technological output and innovative capabilities (Hall, Jaffe, & Trajtenberg, 2000). A patent document contains a host of information, including citations to other patents.

Knowledge flows are invisible, and thus are very difficult to capture or trace empirically. However, patent citations leave behind a trail of how a new piece of technological knowledge builds on existing knowledge (Singh, 2005). As a result, patent citations have been used widely in research as a way to capture knowledge flows (Almeida, 1996; Jaffe & Trajtenberg, 2002; Singh, 2004; Song et al., 2003). We use patent (citation) data to shed light on knowledge flows from host countries to MNC-HQs in home countries. We elaborate on the pros and cons of using patent (citation) data to trace knowledge flows in the Appendix.

For a variety of reasons, the semiconductor industry is a particularly appropriate arena for studying international technology flows. First, it is innovation intensive. Ziedonis (2004), in her study of innovative activities in the semiconductor industry, suggested that patenting activities are more frequent in globally fragmented technology markets such as the semiconductor market. Second, although not all innovations are patented, the incentives for patenting are strong in the semiconductor industry: thus patenting is commonly practiced (Almeida, 1996; Kortum & Lerner, 1999), and is considered vital to maintaining technological competitiveness. Third, the semiconductor industry is global, with major players from the US, Japan, Europe, Korea, Taiwan, and elsewhere (Podolny & Stuart, 1995). Finally, many semiconductor firms have set up R&D labs overseas to source knowledge from host countries. According to Almeida and Phene (2004: 852–853), ''since the early 1980s and by the 1990s, every leading firm in the semiconductor industry has moved towards much greater internationalization of their technology development, including overseas research and design activities.'' Their data analysis shows that in 1997 every major firm in the industry designed semiconductors in all three of the major regional bases of the industry: North America, Europe, and Asia. Because a firm must patent in a specific country to gain intellectual property protection in that country, and because the US is the world's largest technology market, non-US firms routinely file patents in the US (Albert, Avery, Narin, & McAllister, 1991). Thus we use US patent data for more objective comparisons of patent counts of MNCs from various countries with different intellectual property regimes. Based on the advice of patent examiners in the US Patent Office, we identified patent (technology) classes that constituted semiconductor-related technology.[3] We considered patents with primary technology classes that fell into one of the groups listed in note 3 as semiconductor patents.

For the empirical analysis, we identified MNCs that have at least one R&D lab in foreign countries. All companies with patents registered in the semiconductor-related technology classes in the US were included as potential sample companies in our study. From our US patent database, we identified 215 companies initially. Among them, we selected 65 companies that had overseas subsidiaries with at least one US patent granted between 1990 and 1994. Since we counted patent citations made between 1995 and 1999 in our regression analysis, reflecting a time lag in patent citations, we included overseas R&D labs set up before 1995 only in our samples. The total number of overseas R&D labs in our sample is 147. Headquarters of MNCs in our sample are located in 11 home countries. The total number of host countries in our sample is 20,[4] including the US, Canada, 11 European countries, Japan, Korea, Taiwan, China, Singapore, Australia, and Israel.[5] Table 1 shows the regional distribution of both home and host countries. Table 2 shows the number of patents granted to selected home and/or host countries in our sample. Relative advantages between the two countries can be easily identified by comparing country-level patent counts in the table. Not surprisingly, the US has the most semiconductor patents, and Japan follows suit.

Table 1 Description of data

Number of firms	65
Average number of overseas labs per firm	2.26
Number of firms by region (total: 11 home countries)	
North America (USA, Canada)	28
Europe (Germany, France, Sweden, UK, Finland, Holland)	16
Japan	13
Asia (Korea, Taiwan)	8
Number of host countries by region (total: 20 host countries; 147 overseas labs)	
North America (USA, Canada)	43
Europe (Germany, France, Sweden, UK, Finland, Holland, Italy, Switzerland, Spain, Norway, Denmark)	68
Japan	19
Asia (Korea, Taiwan, China, Singapore)	11
Israel and Australia	6

Table 2 Number of semiconductor-related patents granted to selected home/host countries between 1990 and 1994 at USPTO

Country	*Number of patents*
USA	18,184
Japan	13,616
France	880
Germany	838
South Korea	575
Italy	251
Taiwan	216
Canada	169
Switzerland	125
United Kingdom	103

Methods and Variables

We employ negative binomial regressions to investigate the factors influencing the level or the magnitude of knowledge sourced from host countries where overseas R&D labs were set up. A significant over-dispersion problem justifies the use of negative binomial regressions instead of Poisson regressions.[6] We clustered standard errors by MNCs as well, since our data include multiple observations with respect to each MNC. The dependent variable is the number of citations (c_{ij}) made by the home-country headquarters of MNC i from each host country j in which the MNC has overseas R&D labs. When we computed the dependent variable, we excluded self-citations made to their own R&D labs in the host countries. To reduce a potential bias from yearly fluctuations of patent citation counts, we summed up patent citation counts for the observation period that spans 1995 to 1999.

Independent variables are measured by summing up patent citation counts in the preceding 5-year period that spans 1990 and 1994, reflecting a substantial time lag between patents granted and those cited later. We standardized each independent variable by subtracting its mean and then dividing by its standard deviation $\left((X_i-\bar{X})\Big/\sqrt{\sum(X_i-\bar{X})^2\big/(n-1)}\right)$ so that different scales for independent variables could not affect magnitudes of coefficients. Following Ahuja (2000), we operationalized the technological capabilities of MNC-HQs (Hypothesis 1) as the number of US patents granted to MNC-HQs during the period between 1990 and 1994.

An MNC's technological leadership in its home country (Hypothesis 2) is measured by the ratio of the number of patents granted to the MNC-HQ to the total number of patents granted to the home country between 1990 and 1994. As the ratio increases, the focal MNC is regarded as being more dominant in its home country. The relative difference in a home country's and a host country's technological capabilities (Hypothesis 3) is measured by the ratio of the number of US patents granted to the home country of an MNC to that granted to the host country where an overseas R&D lab is located. Finally, technological profiles of an MNC-HQ and a host country are defined as the shape of the distribution over the semiconductor-related technological classes we chose. Following Rosenkopf and Almeida (2003: 759), we measure similarity or dissimilarity of technological profiles (Hypothesis 4) between the MNC-HQ and the host country by Euclidean distance.[7] Again, Euclidean distance is measured based on the patents granted between 1990 and 1994.

We control for the significance of innovative activities in an overseas lab by subtracting the total number of patents granted to the MNC-HQ from the number of patents granted to the subsidiary R&D lab and then dividing the result by the total number of patents granted to the host country. Thus our measure reflects how significant innovative activities of an overseas lab are, relative to those of the MNC-HQ and the host country. The rationale for our choice of this relative measure is as follows. For instance, Alcatel Network System, a US subsidiary of Alcatel headquartered in France, produced 30 patents during the observation period. Similarly, the Canadian subsidiary of IBM yielded 31 patents. Although these two R&D labs registered almost the same number of patents, the numbers may have quite different meaning to their MNC-HQs. The headquarters of Alcatel N.V. was granted 111 semiconductor patents, whereas IBM had 2748 patents during the observation period. Thus 30 patents from its subsidiary would be considered more significant to Alcatel than to IBM. Similarly, the same number of patents would be considered more significant in the host country granted a few patents than in the host country granted a substantial number of patents. We also control for the total number of citations made by an MNC-HQ and the total number of US patents granted to a host country.[8]

RESULTS

Table 3 presents descriptive statistics. Table 4 summarizes the statistical findings from the negative binomial regressions. The base model is composed of control variables only. We added MNC-HQs' technological capabilities variables in Equation (1). Equation (2) is a full model that includes relative capabilities. Equation (3) shows incidence rate ratios of the full model.

MNC-HQs' technological capabilities variables improved Equation (1)'s explanatory power significantly (p-value <0.001). In Equation (2), we added relative capabilities variables. These variables improved the explanatory power significantly (p-value <0.001). In the full model, the coefficient of the quadratic term of MNC-HQs' technological capabilities was highly significant and negative, while the coefficient of the linear term was significant and positive, thereby suggesting the inverted U-shaped relationship. The inverted U reached its peak within the observed range for MNCs' technological capabilities (see Figure 1). This result supports Hypothesis 1, suggesting that MNC-HQs with moderate levels of technological capabilities will source knowledge from a host country more than do MNC-HQs with lower or higher levels of technological capabilities.

With regard to relative capabilities, the coefficient of "the ratio of the number of patents granted to home countries to those granted to host countries" was significant and negative, supporting Hypothesis 3. This result shows that when home countries have strong capabilities relative to host countries, innovative opportunities in home countries may increase, with an attendant decrease in the extent to which knowledge is outsourced. However, we did not find a supporting result for Hypothesis 2 regarding technological capabilities of MNC-HQs relative to their home countries.[9] The results also did not support Hypothesis 4 on differences in technological profiles between an MNC-HQ and a host country. As for control variables, all three – the total number of an MNC-HQ's patent citations, the number of patents granted to the host country, and the significance measure of overseas R&D lab activities relative to the MNC and the host country – were highly significant statistically.

We calculated multipliers in order to estimate the effect of a particular independent variable on citation rates, holding other variables constant (Table 4, column 3). Figure 1 shows the multiplier effects of the number of patents held by an MNC-HQ in which the denominator of the multiplier was calculated by exponentiating the product of the estimated coefficient and the mean value of the number of patents (=742 patents). For example, the multiplier is 1.045 when an MNC-HQ had 10% more patents than the mean value. Since increases or decreases in the citation rate can be calculated as the multiplier minus one, having 10% more patents than the mean value increases the citation rate by 4.5%. The citation rate is predicted to be about 25% higher at its maximum when the number of patents is 1,534 than at the mean number of patents. However, the citation rate of an MNC-HQ with 2,500 patents is 10% less than an MNC-HQ with the mean number of patents (multiplier=0.8967).

In order to estimate the effect of the ratio of the number of patents granted to home countries to those granted to host countries, we estimated the multiplier over the range between its minimum (=0.003) and the mean value (=157.3). The minimum value corresponds to the case in which the home country is Sweden and the host country is USA. The case closest to the mean value in our sample is the one in which the home country is

Table 3 Summary of descriptive statistics

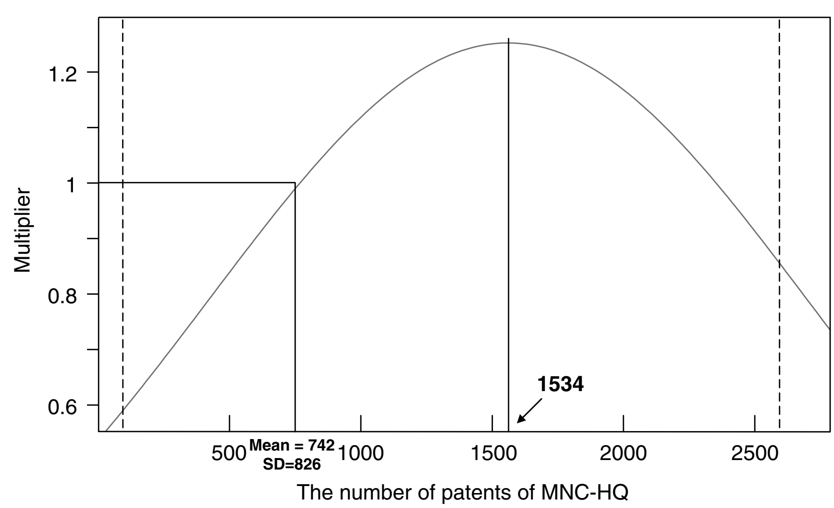
Variable	*Mean*	*Std dev.*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1. Number of citations made by MNC-HQs in host country (dependent variable)	233.5	498.03	0.41	0.56	0.17	0.22	−0.08	−0.07	−0.20
2. Total number of citations made by MNC-HQs	1022.4	1100.7	—	−0.06	−0.43	0.78	−0.10	0.20	0.06
3. Number of patents granted to host country	7953.4	10008	—	—	0.30	−0.23	−0.12	−0.13	−0.12
4. Significance of overseas R&D lab activities relative to MNC and host country	16.5	44.80	—	—	—	−0.55	−0.01	−0.53	−0.15
5. Number of patents granted to MNC-HQ	741.8	826.33	—	—	—	—	−0.04	0.23	−0.05
6. MNC-HQ/Home country	0.48	0.441	—	—	—	—	—	−0.04	−0.03
7. Home country/Host country	157.3	970.3	—	—	—	—	—	—	0.30
8. Euclidean distance in technological profiles between MNC-HQ and home country	0.34	0.26	—	—	—	—	—	—	—

Means and standard deviations presented in this table are obtained prior to standardization.

Table 4 Results of negative binomial regressions (n=147)

	Base model	*Equation 1 (absolute capabilities)*	*Equation 2 (full model)*	*Equation 3 (incidence rate ratio)*
Number of total citations (Control)	1.1622**	1.0763**	1.0798**	2.9441**
	(0.1410)	(0.1946)	(0.1900)	(0.5596)
Number of patents granted to host country (Control)	1.5442**	1.6023**	1.5548**	4.7343**
	(0.0822)	(0.0750)	(0.0846)	(0.4008)
Significance of R&D lab activities relative to MNC and host country (Control)	0.6791**	0.6321**	0.6040**	1.8295**
	(0.0962)	(0.0837)	(0.0793)	(0.1451)
Number of patents granted to MNC-HQ (Hypothesis 1)		0.5717**	0.4671*	1.5954*
		(0.1947)	(0.2168)	(0.3459)
(Number of patents granted to MNC-HQ)^2 (Hypothesis 1)		−0.3064**	−0.2436*	0.7837*
		(0.0912)	(0.1055)	(0.0826)
MNC-HQ/Home country in terms of patent counts (Hypothesis 2)			−0.0123	0.9877
			(0.0414)	(0.0409)
Home country/Host country in terms of patent counts (Hypothesis 3)			−0.0983*	0.9062
			(0.0460)	(0. 0417)
Euclidean distance in technological profiles between host country and MNC-HQ (Hypothesis 4)			−0.1606	0.8515
			(0.1300)	(0.1107)
(Euclidean distance in technological profiles)^2 (Hypothesis 4)			0.0422	1.0431
			(0.0610)	(0.0636)
Log-likelihood	−695.78	−685.06	−683.19	−683.19

*Significant at $p<0.05$ level; **significant at $p<0.01$ level.
Numbers in parentheses are standard errors.



Vertical dotted lines represent the observed range of the number of patents held by MNC-HQs.

Figure 1 Multiplier of the citation rate of MNC-HQs.

USA and the host country is Switzerland, resulting in the ratio of 191.8. According to our estimate (multiplier=0.9844), the ratio variable accounts for decrease of 1.6% in the citation rate.

DISCUSSION AND CONCLUSIONS

Statistical findings from negative binomial regressions show inverted U-shaped relationships between an MNC-HQ's technological capabilities and the level of knowledge outsourcing from a host country (Hypothesis 1). We also find that MNC-HQs' knowledge sourcing from host countries increases when host countries are technologically superior to home countries (Hypothesis 3).

In addition to addressing a previously unexplored empirical question, this paper advances the theory of how MNCs learn from technology-seeking FDIs. Our finding that MNC-HQs' technological capabilities are in an inverted U relationship with the likelihood of sourcing knowledge from the host country has implications for research in the management of innovation, which stresses the importance of external knowledge to innovation. Although absorptive capacity is viewed as a source of competitive advantage, prior studies that advanced this perspective often played down the potential negative consequences of such capabilities, thereby proposing a linear relationship between a firm's technological capabilities and the level of knowledge outsourcing (Zahra & George, 2002). Since a firm with a strong existing knowledge base is more likely to have established idiosyncratic technological trajectories, and thus exhibit path-dependent search behavior, its knowledge base may reduce its receptivity to externally sourced knowledge beyond a certain threshold level of the firm's technological capabilities. Firms fitting this description face the challenge of balancing and building exploitative and exploratory abilities (March, 1991). We believe such motivational factors that underlie learning and absorptive capacity are important even in domestic settings.

This paper also proposes and empirically shows the importance of relative capabilities in determining the level of knowledge sourcing from host countries. Prior research in organizational learning, including studies in international contexts, mostly ignored how relative levels of technological capabilities influence MNCs' motivations to acquire external knowledge. Our results suggest that relative levels of capabilities may be as important as absolute levels of capabilities when MNC-HQs source knowledge from host countries of their R&D labs.

Specifically, consistent with previous studies such as Kuemmerle (1999) and Frost (2001), we found that when a host country has stronger technological capabilities than a home country, an MNC-HQ tends to outsource knowledge more actively from the host country. This finding has some implications for an MNC's location decisions for its overseas R&D operations. When an MNC makes location decisions for its overseas R&D labs, it would consider its home country's relative technological strengths and weaknesses as compared with those of the host country. For example, if a potential host country has technologies that a home country lacks or lags behind in, then the country will clearly enjoy higher status as opposed to other host countries that do not have such advanced technologies in the same area. This argument is consistent with Cantwell and Janne's (1999) finding that overseas subsidiaries of technologically advanced MNCs tend to conduct R&D activities in technologies that they lack or lag behind in.

Finally, consistent with Singh (2004), our finding that the significant technological activities of an overseas R&D lab have a positive impact on the knowledge flow from the host country to the MNC-HQ implies the importance of the overseas R&D lab as an effective intermediary of knowledge sourcing by an MNC-HQ in the global network. As an overseas lab improves its technological capabilities and absorptive capacity, it becomes more able and likely to seek knowledge from the host location as a basis of its innovative activities. In the process, the parent company appears to improve its information and absorptive capacity in terms of the locally embedded knowledge in the host country of its own R&D lab.

Empirically, we believe that this is the first attempt to investigate how overseas R&D activities of MNCs can influence R&D activities at home, where most MNCs still keep core innovative activities. Moreover, unlike most previous empirical studies of knowledge-seeking FDI, this paper attempted to measure the degree of knowledge sourcing from the host country more directly by tracing the level of knowledge flow captured by patent citation counts.

However, this paper has some limitations. Because of data constraints, we could not examine either the specific mechanisms that MNCs employ to facilitate knowledge transfer or the role of overseas subsidiary mandates in knowledge sourcing from host countries. We believe that future research along these lines will enrich our understanding of how MNC-HQs source knowledge from host countries and their overseas R&D operations. Although we believe that our findings can be generally applicable to other technology-intensive industries where patenting innovative outputs is important, we admit that such a claim is an empirical question. Thus we also suggest that future research should be conducted in other industrial settings to check the generalizability of our findings in this study.

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NOTES

[1]The fact that knowledge spills over more efficiently in clusters can also have a negative impact on a firm's incentives to locate within a cluster, as rivals can benefit from a focal firm's R&D efforts (Flyer & Shaver, 2003).

[2]The diminished motivation may derive from the path-dependent nature of search behaviors, lower economic incentives due to overlaps in knowledge bases, or the difficulty associated with creating new routines to incorporate geographically dispersed knowledge.

[3]Semiconductor-related technology classes are 29, 156, 257, 326, 327, 357, 364, 365, 395, and 437.

[4]In our sampling scheme we focused exclusively on host countries where overseas R&D labs had already been set up by MNCs. We chose this sampling scheme because our main research question was to investigate under what conditions MNC-HQs source knowledge more actively from the host countries of their R&D labs. In other words, in this study we examined how variations in technological capabilities affect the level of knowledge sourcing from host locations.

[5]Some recent studies (e.g., Chung & Alcacer, 2002; Chung & Song, 2004) have been conducted at a smaller regional level of analysis such as the state, although much of the prior empirical research in this area has been conducted at the country level. We also conducted a multi-country study, mainly because of technical difficulties in classifying regions in systematic and comparable ways for the purposes of empirical research, especially in the international setting. For example, it would be difficult to say that states in the United States are comparable to provinces in China, or that Silicon Valley is comparable to the Shinju Science Park in Taiwan.

[6]The Poisson regression model is a special case of the negative binomial: it corresponds to $\alpha=0$. In order to test $\alpha=0$ STATA performs a likelihood test, as shown at the bottom of Table 4. In our full model the probability that we would observe this data conditional on $\alpha=0$ is virtually zero, thereby suggesting a significant over-dispersion problem in the data.

[7]Two popular distance measures for multivariate situations are Euclidean distance and Mahalanobis distance. The latter is preferred when the variables under consideration have different scales. We measured similarity or dissimilarity of technological profiles between an MNC and a host country by Euclidean distance as follows:

$$\text{Euclidean distance} = \sqrt{\sum_{i=1}^{10} (\text{MNC}_i - \text{HC}_i)^2}$$

where

$$\text{MNC}_i = \frac{\text{The number of patents in patent class } i \text{ granted to the MNC}}{\text{The total number of patents granted to the MNC}}$$

and

$$\text{HC}_i = \frac{\text{The number of patents in patent class } i \text{ granted to the host country}}{\text{The total number of patents granted to the host country}}$$

[8]We did not include firm size as a control variable, mainly because of the multicollinearity problem between firm size and the number of a firm's patents (Ahuja, 2000: 329). In addition, we had difficulties extracting the figures of sales or employees of the multidivisional firms in our internationally dispersed samples.

[9]We conducted sensitivity tests using different time frames such as 1994–1999 and 1996–1999, but the statistical results did not change much, thereby showing the robustness of our findings.

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APPENDIX

Pros and Cons of Using Patent (Citation) Data to Trace Knowledge Flows

Patents represent externally validated measures of innovative success and can therefore be interpreted as signals of technological competence (Narin, Noma, & Perry, 1987; Ahuja, 2000). Past research established that the patenting record of firms is closely related to their stature in the technological arena (Jaffe & Trajtenberg, 2002). Patent data have received so much attention because they are systematically compiled, have detailed information, and are available continuously across time.

However, using patent data as a proxy for technological capabilities may have some drawbacks. First, the propensity of a firm to patent its innovations varies substantially across industries (Mowery et al., 1998; Kortum & Lerner, 1999). The semiconductor industry that we investigate was found to be one of the most patent-intensive industries (Kortum & Lerner, 1999). Second, because a patent itself represents codified knowledge, there is some difficulty in capturing the tacit knowledge of a firm using patent data. However, Mowery et al. (1998) suggest that knowledge flows are closely linked between codified knowledge and tacit knowledge because they are not substitutes, but complements. Third, according to Hall and Ziedonis (2001), a pro-patent legal shift in the 1980s encouraged capital-intensive firms to increase the number of patents substantially for strategic reasons, even if they continue to rely on other mechanisms for appropriating returns to R&D investments, such as lead time and superior manufacturing and design capabilities rather than patents.

Although patent citations have been used widely in research as a way to capture knowledge flows, they also have some drawbacks as an accurate measure for capturing knowledge flows (Singh, 2005: 759). First, patent citations might be included by the inventor for strategic reasons such as avoidance of litigation. Second, patent citations could be added by patent examiners as well. Nevertheless, recent studies that compared patent citation data with direct surveys of inventors found that the correlation between patent citations and actual knowledge flow is high, thereby justifying the use of patent citation as a proxy measure of knowledge flows (Jaffe & Trajtenberg, 2002). Thus we also believe that, in spite of some disadvantages, patent citations are probably the best proxy measures of knowledge flows available for empirical studies. Given the high propensity of patenting in the semiconductor industry, patent citations could be effective in capturing knowledge flows in the industry, as shown by such studies as Almeida (1996), Almeida et al. (2002), Song et al. (2003), and Ziedonis (2004). For example, Ziedonis (2004) suggested that innovative activities in the semiconductor industry are highly cumulative because they often build on a large stock of prior inventions.

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