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SUBSIDIARIES AND KNOWLEDGE CREATION: THE INFLUENCE OF THE MNC AND HOST COUNTRY ON INNOVATION

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This paper studies the influence of external knowledge on innovation in subsidiaries of multinational firms. The focus on subsidiaries is especially interesting since they are simultaneously embedded in two knowledge contexts: (a) the internal multinational corporation (MNC) comprised of the headquarters and other subsidiaries; and (b) an external environment of regional or host country firms. We develop hypotheses to suggest that the extent of influences of these contexts on subsidiary technological innovation depends on the characteristics of the knowledge network (technological richness and diversity) and the knowledge linkages of the subsidiary with other entities. The study uses patent citation data pertaining to innovations by foreign subsidiaries of U.S. semiconductor firms to test these hypotheses. The paper finds that (a) the technological richness of the MNC, (b) the subsidiary's knowledge linkages to host country firms, and (c) the technological diversity within the host country have a positive impact on innovation.

INTRODUCTION

Researchers in strategy and organization theory have long acknowledged the influence of a firm's context on its behavior and performance. Though early studies in the resource-based view of the firm highlighted the role of heterogeneous, inimitable resources within a firm in the creation of competitive advantage (Barney, 1991; Rumelt, 1974), recent research points to the potential of external resources in creating firm competitiveness (Gulati, 1999). Even for external resources, some firms have preferential access to them by virtue of location (Almeida and Kogut, 1999), participation in networks (Gulati, Nohria, and Zaheer, 2000), and through the development of interfirm processes to access these resources (Dyer and Singh, 1998).[1]

The subsidiaries of the multinational corporation (MNC) have the potential to access resources from two distinct knowledge contexts. First, subsidiaries are, of course, a part of a MNC that has the capacity to share knowledge across its various units (Bartlett and Ghoshal, 1989). Second, subsidiaries are located in host country regions that often embody social, professional, and technological relationships among firms permitting interfirm knowledge flows (Porter, 1990). Andersson and Forsgren (2000) suggest that resource interdependencies with these two contexts (the MNC and host country) may influence the development of

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[1] While strategy studies tend to suggest a proactive role for the firm in resource acquisition, organization theory has tended to be skeptical about voluntarism and relied more on arguments of environmental selection. However, both areas agree that environmental influences on resource availability to a firm are important.

knowledge and capabilities within multinational subsidiaries. In this paper we evaluate the influence of the MNC and the host country on the innovative ability of MNC subsidiaries.

Though all subsidiaries are part of an MNC and located in a host country network, they do not have equal access to knowledge resources. This paper posits that the differential innovative ability of subsidiaries can best be understood by examining both the characteristics of the (MNC and host country) contexts in which subsidiaries are embedded, and the relationships of the subsidiaries with other firms in these contexts. Hence we look at the roles of technological richness and diversity of the MNC and host country network and the knowledge linkages of the subsidiary with other entities in these networks.

We use patent citation data pertaining to innovations by foreign subsidiaries of U.S. semiconductor firms to analyze the contextual influences on subsidiary innovation. Regression analysis reveals that knowledge linkages with firms in the host country and technological diversity of the host country positively influence subsidiary innovation. We find that only the technological richness of MNC affects the innovative output of the subsidiary.

This study's contribution is along two dimensions. First, though previous research has emphasized the importance of knowledge acquisition and exploitation for the MNC and its subsidiaries, there is still need for a better theoretical and empirical understanding of the knowledge exchange phenomenon (Zander and Solvell, 2000). We study here the effects of knowledge access by the subsidiary from both the internal MNC network and the external host country network.[2] We believe this focus on the influences on subsidiary innovation will help the further understanding of the sources of innovation and knowledge development for the subsidiary and hence the MNC. Second, our study seeks to take the next step, not just by comparing relative influences, but pointing to the conditions that determine the strength of internal and external influences on subsidiary innovation.

In the next section, we discuss the existing theory and develop hypotheses to explain the relationship between MNC and host country knowledge and subsidiary innovation. The following section discusses the use of patent citation and other data and describes the tests performed. The final section presents our findings and discusses the results of the study.

THEORY DEVELOPMENT AND HYPOTHESES

The MNC and knowledge flows

The idea that foreign direct investment is driven by a firm's knowledge assets can be traced back to the pioneering work of Hymer (1976) and the subsequent developments by Caves (1971) and Buckley and Casson (1976). The process by which an MNC creates value from knowledge was initially conceptualized as a linear sequence: knowledge was created in the firm's home base (typically at the headquarters) and was then diffused to subsidiaries worldwide in the form of new products and processes. Subsidiaries were thus seen as entities that applied and exploited knowledge sourced from the headquarters.

During the last decade, as a result of theoretical and empirical research into international firms, the traditional view of how the MNC creates value from knowledge has evolved and with it the view of the subsidiary. Central to Perlmutter's (1969) 'geocentric' firm, Bartlett and Ghoshal's (1989) 'transnational' corporation, and Hedlund's (1994) 'N-form' corporation is the idea that technical, market, and functional knowledge is sourced from various locations and generated continuously in all parts of a company, and shared across the organization. In this networked corporation, an important role in the innovative process (in terms of accessing, sharing, and creating knowledge) is played by the subsidiaries. Differentiation between the subsidiaries of the MNC also appears to be conducive to knowledge creation. Zander (1997) points to the tendency for overseas subsidiaries to specialize in developing particular technologies. Thus the subsidiary can be seen to benefit from not just headquarter (and home country) knowledge but also knowledge accessed by other affiliates of the MNC from areas having varied market and technological specialization.

These insights into the role of the MNC in generating and leveraging knowledge have stimulated research into the processes through which

[2] Typically empirical literature has focused on either knowledge exchange within the MNC (Gupta and Govindrajan, 2000; Lord and Ranft, 2000) or within the host country region (Almeida, 1996).

knowledge flows are managed and the mechanisms that underlie the creation of a knowledge network within the multinational (Gupta and Govindrajan, 2000). The knowledge-based view of the firm points to the central role of the firm in providing a set of 'higher-level organizing principles' and a rich social context to support the creation, transfer, and integration of knowledge (Kogut and Zander, 1992, 1996). This research has directed attention to the importance of informal and lateral structures and systems. Ghoshal, Korine, and Szulanski (1994) identify the important role of interpersonal networks among the subsidiary managers of Philips and Matsushita, while Gupta and Govindrajan (2000) also show how informal mechanisms promote knowledge flows within MNCs. Almeida, Song, and Grant (2002) demonstrate that the MNC's use of multiple formal and informal mechanisms (including structure, management systems and processes, culture and leadership) permit it to transfer product and process knowledge (often having tacit and codified components) across borders. Of course, MNCs vary in the degree to which these mechanisms are efficiently employed and thus in their ability to move, build, and exploit knowledge across the network.

The host country and knowledge flows

External learning from host country locations can be a potent source of value creation for MNCs. As with the view of the MNC, the view of the host country has changed in the more recent literature in international strategy. While host countries were originally seen primarily as markets or as sources of cheap labor for the MNC, increasingly host country regions are seen as potential sources of new knowledge (Dunning, 1994). Common to Alfred Marshall's (1920) 'industrial districts' and Porter's (1990) localized, industry 'clusters' is the idea that industry-specific knowledge develops in geographically concentrated locations. Recent research on national innovation systems suggests that the national institutional context may play an important role in explaining the patterns of innovation within and across countries (Nelson, 1993; Westney, 1993). This literature suggests that countries develop specific technological trajectories that are shaped by the dynamic interaction of political, economic, and educational systems with industrial systems across time (Bartholomew, 1997). This view is supported by empirical studies that have substantiated that patterns of sectoral technological specialization are distinct across countries (Cantwell, 1989; Patel and Pavitt, 1991).

One of the reasons for the growth of technologically specialized regions is that the flow of knowledge may be geographically localized. Jaffe, Trajtenberg, and Henderson (1993) analyzed patent citation data to demonstrate that firms and universities acquire knowledge from others in geographically proximate locations. A key reason for geographically localized knowledge flows, research suggests, is the establishment of interfirm (and interpersonal) linkages between firms in the region. Some regional relationships may be formal, such as alliances and supply relationships (Von Hippel, 1988) but are often facilitated by ongoing informal personal interactions. Proximity also facilitates the creation of regional social networks (Rogers and Larsen, 1984) and permits the mobility of engineers within technologically specialized regions (Almeida and Kogut, 1999). Saxenian (1990) relates the dynamism and the vitality of Silicon Valley to the extensive networking both at the firm level (between firms and universities, buyers and suppliers, venture capitalists, etc.) and also between individuals within the region. Research points to the sharing of partially developed emergent knowledge and mostly tacit, market, and technological knowledge through regional networks (Saxenian, 1994). Though product knowledge seems to flow through regional networks, process knowledge appears to be stickier.

Thus through the location of subsidiaries in technologically advanced regions, MNCs can gain access to knowledge embodied within them. Almeida (1996) has shown that the U.S. subsidiaries of foreign MNCs draw heavily upon the technology of local companies in their knowledge building. Shan and Song (1997) found that in the biotechnology industry foreign MNCs make equity investments in American biotechnology firms with high levels of patent activity, thus sourcing country-specific, firm-embodied technological advantages.

Subsidiary roles, knowledge resources, and innovation

Though every subsidiary has the potential to access and use knowledge resources from both the MNC and the host country, the relative importance of alternate knowledge sources is likely to be influenced by the subsidiary mandate and strategy, or the role that it plays within the MNC network.[3] While the early conceptualization of the MNC subsidiary suggested a market-seeking or knowledge exploitation role, subsequent research suggests that subsidiaries play a variety of roles within the MNC (Birkinshaw and Hood, 1997; Jarillo and Martinez, 1990). For instance, subsidiaries can be seen to be either market-seeking units or resource-scanning units (Dunning, 1994; Porter, 1990). Similarly Birkinshaw and Hood (2000) contrast subsidiaries that are essentially 'product specialists' with limited expertise and focus and those with a 'world mandate' that have broad responsibilities, considerable autonomy within the MNC, and extensive capabilities in research and development. Many researchers have focused on varying subsidiary roles particularly with respect to R&D (Bartlett and Ghoshal, 1989; Kogut and Chang, 1991). In an important classification, Kuemmerle (1997) points out that, sometimes, subsidiary R&D is needed to adapt existing products to local needs. He calls this home-base-exploiting R&D. He contrasts this with subsidiaries that conduct R&D to expand the MNC knowledge base by sourcing knowledge from local institutions including universities, research labs, and competitors. This is labeled 'home-base-augmenting' R&D.

Thus a common theme underlying much of the research on subsidiary strategies and mandates with respect to R&D and innovation suggests that subsidiaries may be broadly classified as those with an exploitation mandate (which primarily conduct R&D to exploit existing MNC knowledge) and those with an exploration mandate (which conduct R&D to augment existing MNC knowledge). Though both types of subsidiaries may innovate, the subsidiary R&D orientation can be expected to have an impact on the relative importance of knowledge sources in the MNC network and the host country network. For instance, subsidiaries with an exploitative role may be more dependent on MNC knowledge, but subsidiaries with an explorative role may be more likely to seek host country knowledge.

Malnight (1995) suggests that MNC subsidiaries gradually evolve from those that leverage home country capabilities in local markets to those that build new expertise with host country inputs and facilitate the exploitation of these innovations throughout the MNC system. The roles that subsidiaries play often change and, at a particular time, are a result of the dynamic interaction of many factors including the headquarter mandate, internal subsidiary decision making and strategy, and host country characteristics (Birkinshaw and Hood, 2000). Thus, the distinction between subsidiaries that exploit home-based knowledge and those that augment home-based knowledge may often be blurred. Recent research into knowledge management and the knowledge-based view of the firm has established that, while knowledge generation (or 'exploration') and knowledge application (or 'exploitation') may be conceptually separate activities (March, 1991), these activities are closely complementary. Cohen and Levinthal's (1990) study of knowledge transfer suggests that if the capacity of the recipient organization to absorb new knowledge is a function of that recipient's knowledge base, then the exploitation of existing knowledge cannot be separated from its augmentation. Given this reasoning, it is not surprising that a recent empirical study by Kuemmerle (2002) points out that increasingly subsidiaries often play both roles—they simultaneously exploit their existing knowledge bases and augment their knowledge through innovation. Hence our study does not focus on the varied roles played by R&D-conducting subsidiaries, but it controls for differing subsidiary roles since these could affect the incentives to exploit MNC and host country knowledge differently.

HYPOTHESES DEVELOPMENT

The characteristics of the MNC or host country network (in addition to subsidiary characteristics) play a significant part in determining subsidiary access to resources. Studies using network approaches and methodologies suggest that strength of network influences on firms are related to the characteristics of the network (including the extent and quality of resources available) and the position of the firm *vis-à-vis* others in the network (Galaskiewicz and Zaheer, 1999).[4] Thus we

[3] We thank two anonymous reviewers for pointing to the importance of subsidiary roles in subsidiary innovation.

[4] These and several other studies have used network approaches to study environmental influences on firm performance. Though our data do not permit the use of network methodologies, we nevertheless draw upon their observations and insights.

develop hypotheses regarding the effect of (a) the characteristics of the two networks, and (b) the extent of knowledge linkages between the subsidiaries and other firms in the network on subsidiary innovative performance.

Technological richness

The idea that innovation arises from the recombination of existing knowledge is now well established (Grant, 1996). Galunic and Rodan (1998) suggest that merging of knowledge from different sources is an essential driver of firm innovation and perhaps performance. In fact, the recombination of existing knowledge from different sources to facilitate (technological or managerial) innovation can be viewed as one of the fundamental functions of an MNC (Kogut and Zander, 1992). The greater the extent of knowledge resources in the network, the greater is the opportunity set presented to firms located in it to access knowledge (Gulati, 1999) and therefore innovate through merging their own knowledge with acquired knowledge. The importance of scale or richness of knowledge within a network would not be so critical if all knowledge flowed easily to members in a network. But this is not so. One of the key findings in the area of knowledge management is that knowledge does not flow easily from one unit to another even within a firm (Grant, 1996). Szulanski (1996) points out that for a variety of individual and organizational reasons knowledge is sticky and does not move easily from one part of the firm to the other despite organizational efforts. Within regions, too, not every firm has access to all the knowledge generated there (Almeida, Dokko, and Rosenkopf, 2003). Hence networks with greater amounts of knowledge offer greater opportunities for knowledge access and hence greater possibilities for innovation.

However, not all networks are equally innovative or 'rich' in knowledge. Subsidiaries belonging to MNCs that innovate very little, or that are oriented primarily towards the exploitation of existing technologies, may have relatively limited chances to acquire new knowledge to be used in the innovative process. Secondly, these MNCs may not have developed sophisticated systems and processes for innovation, thus leaving their subsidiaries comparatively disadvantaged, not just with respect to the acquisition of technological knowledge but also regarding the procedures and practices that enhance innovation. Similarly, not all regions offer the same potential for innovation. Almeida and Kogut (1999) show that not only do regions differ in their levels of knowledge creation but also that the most innovative regions tend to have the greatest levels of knowledge localization (making knowledge accessible primarily to geographically proximate firms). We look at network technological richness as the extent to which new knowledge is created within the (MNC or the host country) networks. Hence, all else being equal, subsidiaries in resource-rich networks will have greater opportunities for accessing and recombining knowledge from external and internal sources resulting in better innovatory performance.

Hypothesis 1a: Subsidiaries belonging to technologically rich MNCs are more innovative.

Hypothesis 1b: Subsidiaries located in technologically rich host countries are more innovative.

Technological diversity

Not only is the extent of knowledge available to a firm important, but also the nature of this knowledge. It is a well-established fact that firms tend to search for new knowledge in the neighborhood of their current technologies and practices (Nelson and Winter, 1982). However, purely technologically local search restricts the possibilities for innovation through recombinations, since it could block out the acquisition of novel and more distant knowledge. Indeed, Levitt and March (1988) warn of competence traps and Leonard-Barton (1995) suggests that core capabilities associated with existing routines can become core rigidities as circumstances change. Recent studies in the area of strategic management share the view that, given technological change and the dynamic nature of competition, firms must move beyond technologically local search to compete successfully over time (McGrath, 2001). Rosenkopf and Nerkar (2001) demonstrate that external exploration in distant technological domains yields innovations with more impact on a broader set of technological areas. When innovating, the existence of heterogeneous knowledge (perhaps from different perspectives) enriches the possibility of new combinations and thus enhances the likelihood of emergence of novel ideas (Turner and Fauconnier, 1997). Henderson and Cockburn (1996) point out the benefits of diversity in research agendas of pharmaceutical firms. They suggest that a range of research approaches and expertise within firms permit the cross-fertilization of ideas through knowledge spillovers between units and therefore greater innovative output. Hence, it is not just the amount of knowledge that is accessed but the diversity of technological knowledge resources available to the subsidiary from the MNC or host country that will effect the innovation of subsidiaries by altering the opportunities for new knowledge creation.

Within the MNC, significant opportunities exist for cross-fertilization of knowledge across the specialized and technologically diversified network of firms (Zander and Solvell, 2000). Technological specialization also points to the exploratory role of subsidiaries in high-technology regions. Thus knowledge exchanges with the host country will offer similar opportunities for knowledge combinations due to differences in the approaches, histories, and competencies of various firms in the region. The extent of such cross-fertilization in both networks will be positively influenced by the diversity of knowledge resources within them.

Hypothesis 2a: Subsidiaries belonging to technologically diverse MNCs are more innovative.

Hypothesis 2b: Subsidiaries located in technologically diverse host countries are more innovative.

Knowledge linkages

Though network knowledge may be potentially useful to a firm, it must develop linkages or mechanisms to access and incorporate this knowledge (Dyer and Singh, 1998). Research confirms the important role that linkages between organizations play in influencing firm performance and innovation. Formal or informal connections influence innovation through the creation of trust and reciprocity exchanges (Granovetter, 1992) that encourage knowledge sharing and collaboration, the generation of alternative perspectives on research problems and solutions (Powell, Koput and Smith-Doerr, 1996), and the identification of appropriate referrals to locate new knowledge (Dyer and Noboeka, 2000). Interorganizational relationships serve as an information-gathering device, enabling firms to access information on the research agendas of numerous firms (Rogers and Larsen, 1984), resulting in further innovative activity. The number of relationships (or knowledge linkages) that an organization has with other firms may result in differential access to resources (Powell *et al*., 1996). Recently Ahuja (2000) in his study of firms in the chemical industry also demonstrated the positive effect of the number of direct and indirect linkages on the firm's subsequent innovation output.

Subsidiaries have the potential to develop knowledge linkages within two networks. Within MNCs a range of coordination and integration mechanisms are available to link various entities. However, MNCs differ in the extent to which their affiliates are integrated (Ghoshal and Bartlett, 1990). Industry literature is replete with examples of firms like Phillips or Brown Boveri and Cie that due to strategy (multidomestic) or mindset (polycentric) failed to properly share and exploit knowledge throughout their multinational networks. In host country regions also a range of formal and informal relationships link firms and help the transfer of knowledge. However, here again not every region is networked to the same extent (Saxenian, 1994) and not every firm within a region has an equal number of these relationships. Hence, having a large number of linkages (with the MNC and the host country) is simultaneously expected to increase both the amount and variety of knowledge available to a subsidiary and is expected to lead to more innovation.

Hypothesis 3a: Subsidiaries with more knowledge linkages to the MNC are more innovative.

Hypothesis 3b: Subsidiaries with more knowledge linkages to the host country are more innovative.

DATA AND METHODS

We test our hypotheses on a sample of firms from the U.S. semiconductor industry. Innovation is crucial to the semiconductor industry—its importance is reflected by the significant firm R&D expenditures, which typically exceed 10 percent of revenues (Sorensen and Stuart, 2000). Since the early 1980s and by the 1990s every leading company in the industry has moved towards much greater internationalization of their technology development, including overseas research and design activities. An analysis of patent data reveals that in 1997 every major firm in the industry designs semiconductors in all three of the major regional bases of the industry: North America, Europe, and Asia. The increased dispersion of R&D activities suggests an evolving and important influence of subsidiaries on innovation in the industry's MNCs.

In this paper we use patent data[5] to measure the innovative performance of multinational subsidiaries and to develop measures of the technological richness and diversity (of the MNCs and host countries). Only patents filed under the U.S. patent system are used since every significant firm in the semiconductor industry commonly uses this system. The patent document contains extensive knowledge, useful to the study of innovation and innovative influences. Patent documents provide data on the originating firm, geographic location of the invention, and technology of innovation. In addition, we use patent citation data to infer the 'knowledge linkages' between subsidiaries and other firms, since organizational influences on a particular invention can be inferred from citations. A list of citations for each patent is compiled through a uniform and rigorous process—patent applicants are required by law to reference any and all relevant previous patents (representing the existing knowledge that the current patent builds on) in their patent application. A representative of the U.S. patent office, the patent examiner, further verifies this list of patent citations. The process serves as a safeguard for the integrity of the citation process (Sorensen and Stuart, 2000).

There are, of course, a number of potential limitations to using patent data to study innovation. First, patents and their citations are acknowledgedly a partial measure of the production and exchange of organization knowledge (for instance, they do not always include tacit knowledge such as organizational routines). Our study therefore captures innovation and knowledge exchanges of articulated technological knowledge. However, this limitation is attenuated by the fact that codified knowledge flows (represented by patents) and tacit knowledge flows are closely linked and complementary (Mowery, Oxley, and Silverman, 1996). Another potential drawback in the use of patent data is that patenting is itself a strategic choice and hence all technological innovations may not be patented. However, in the semiconductor industry patenting is actively carried out—every major firm in the semiconductor industry regardless of national origin has an extensive patent portfolio of U.S. patents (Almeida and Kogut, 1999). Patents are used not only to establish property rights but also to facilitate licensing and are used as 'bargaining chips' in negotiations (Von Hippel, 1988). Thus patent portfolios of semiconductor firm subsidiaries measure to a significant extent their innovatory performance.

To create our sample we considered all U.S. firms engaged in the semiconductor industry. This list of firms was compiled using information from Dataquest and Integrated Circuit Engineers. For this set of firms, we identified every overseas subsidiary engaged in innovation between 1981 and 1992. This implies that an overseas subsidiary had to have filed for at least one semiconductor patent during the course of these 12 years, to be included in our sample.[6] This led to a sample of 58 subsidiaries, from seven firms, observed over the 1981–92 period. These subsidiaries were located in 26 different countries in regions including North America, Europe, and Asia. The number of observations in our sample was 374.[7]

Variable operationalization

To test our hypotheses, we use measures created by examining the semiconductor patents (original patents) filed by our sample between 1981 and 1992, and the associated cited patents (cited by the original patents) to infer the knowledge linkages with the host country and the MNC environments.

[5] A patent is the grant of a property right to an inventor for an invention conferred by the government. It establishes the 'right to exclude others from making, using or selling the invention' for a period of up to 17 years. A U.S. patent is granted for an invention that is 'useful', 'novel' and 'non-obvious to a person of ordinary skill in the art' (U.S. Department of Commerce, 1992).

[6] Though the patents by these subsidiaries were limited to the time period mentioned, the citations by these patents covered the period 1971–92.

[7] The number of observations in our sample differs from the expected, 58 subsidiaries multiplied by 12 years, for two reasons: firstly because of the differences in the year of first patenting by the subsidiaries. For example, Intel Germany began patenting in 1986 and therefore contributes only 7 years of observation instead of 12; secondly, due to the lags built into our model, where independent variables were measured at time $t - 1$, the first year of observation, 1981, could not be included in our sample.

Dependent variable

Subsidiary innovatory performance is measured as the number of successful semiconductor patents applied for by the subsidiary in a given year t. We allocated patents to the MNC based on the ownership of the patents (assignees) and within an MNC we allocated patents to specific subsidiaries based on the geographic location of the inventors.

These patent counts were computed only for semiconductor patents. We use USPTO technology class information to classify patents to semiconductors. The U.S. patent system classifies patents into broad technology classes that do not map easily onto SIC codes. There are approximately 400 broad technology classes at the 3-digit level. Our discussion with patent examiners indicated that 20 broad technology classes, encompassing hundreds of 9-digit technology classes, covered the entire spectrum of semiconductor knowledge and contributed to 95 percent of the innovatory activity in the semiconductor industry. Thus subsidiary innovatory performance measures the number of patents filed by the subsidiary in these 20 classes. We use the patent application date of successful patents (or the date that patent was filed with the Patent Office) to indicate the year of innovation.

Independent variables

To compute the technological richness and diversity of the MNC and the host country, we first identified the parent firm (MNC) and the host country for each subsidiary. We then used information from patents belonging to each MNC (a total of 53,062 patents) and each of the host countries (a total of 197,796 patents) in the 12-year period 1981–92 to construct the technological richness and diversity measures. To determine the subsidiary knowledge linkages with the MNC and the host country, we used information from all the patents cited (1250) by every original patent filed by the subsidiary in our sample. We considered cited patents filed between 1971 and 1992.[8] While our dependent variable is measured at time t, all independent variables and controls are measured at time $t-1$.

[8] Data on cited patents filed prior to 1971 were not available. Besides, an analysis of citation trends revealed that most patents were typically cited within 6 years from their application date.

Technological richness: MNC and host country

Technological richness of the MNC or host country is an indicator of the total innovative knowledge that resides within the MNC or the host country network (and is potentially available to the subsidiary to utilize in innovation). It is measured as the number of patents successfully applied for by the MNC (or host country) as a percentage of total worldwide semiconductor patents applied for in year $t-1$. Thus MNC technological richness is calculated as $M_{it-1}/T_{t-1} * 100$, where M_{it-1} refers to number of semiconductor patents applied for by MNC i in year $t-1$ and T_{t-1} is the total number of semiconductor patents applied for in year $t-1$.

Technological diversity: MNC and host country

This variable captures the breadth of the technological knowledge contained in the MNC or the host country. We constructed an index that measures the distribution of the MNC and the host country's patents for every year, across the 20 semiconductor classes. This distribution locates each firm and host country in a multidimensional technology space captured by a K-dimensional vector $f_i = (f_{i1} \ldots f_{ik})$, where f_{ik} represents the fraction of MNC/host country i's patents in patent class k. We then constructed a measure of diversity based on patent data (Jaffe, 1989). Our measure is calculated as follows: MNC diversity $= 1 - [(\Sigma_k f_{ikt-1}{}^2)^{1/2}]$, where f_{ikt-1} is the proportion of MNC i's patents in semiconductor class k, in year $t-1$; and Host country diversity $= 1 - [(\Sigma_k f_{jkt-1}{}^2)^{1/2}]$, where f_{jkt-1} is the proportion of host country j's patents in semiconductor class k, in year $t-1$. The measure ranges from 0 to 1: 0 indicates complete concentration in a single technology class and 1 indicates maximum diversity of innovations across the technology classes. The measure is based on the assumption that the distribution of the patent output reflects the research emphasis of the firm (or region) in particular technologies (Jaffe, 1989).

Subsidiary knowledge linkages

Our measures of subsidiary knowledge linkages (with the MNC or host country) are created using information from patent citations. When a subsidiary cites another patent it suggests that the subsidiary builds on the knowledge of another firm that owns the patent. We use the instance of a citation by the subsidiary to another subsidiary (in the MNC) or firm (in the host country) to indicate a 'knowledge linkage' between the two. The variable 'Subsidiary knowledge linkages' with the MNC is computed as the number of other subsidiaries in the MNC cited by the subsidiary in year $t - 1$. Similarly, knowledge linkages with the host country are captured by the number of host country firms cited by the subsidiary in year $t - 1$.

Controls

We control for subsidiary, firm, and host country characteristics that influence subsidiary innovation. Research suggests that subsidiary mandate in part determines the role of the subsidiary (Birkinshaw and Hood, 1997). We define subsidiary mandate or role in the MNC network by using three control variables that identify its knowledge production behavior. First we examine the subsidiary's prior innovative capabilities, by measuring its knowledge stock. Thus subsidiary innovatory capabilities reflected in its cumulative patenting output are measured as the total number of patents the subsidiary has applied for in the previous 5 years up to and including $t - 1$. *Subsidiary knowledge stock* is a reflection of subsidiary role as a lead innovator (characterized by substantial knowledge stock) or a minor innovator (with limited knowledge stock). Second, we determine *subsidiary focus* by examining patterns of self-citations. This variable is measured as the number of citations that a subsidiary makes to itself in the year $t - 1$. Subsidiary focus reflects the orientation of the subsidiary; a large number of self-citations suggest an inward looking focus and an emphasis on exploitation. A small number of self-cites points to an external orientation and a focus on exploration. The third subsidiary variable controls for an important input to the innovation process: *subsidiary R&D intensity*. In the absence of subsidiary level R&D data, we create a proxy by allocating MNC R&D to subsidiaries on the basis of their share in overall MNC patenting activity. It is calculated as the total MNC R&D expenditure as a percentage of sales, multiplied by the proportion of subsidiary to MNC patents, in year $t - 1$. We expect subsidiaries that have world mandates or are centers of excellence to have higher subsidiary R&D intensity. Subsidiary roles are also driven by the local environmental context (Ghoshal and Nohria, 1989). We therefore include a control related to the host country, a measure of its *gross domestic product* at time $t - 1$, since it may mirror the demands for technological sophistication and innovation that are made on the subsidiary. Thus subsidiaries in locations with greater pressures for technological innovation are more likely to evolve and assume world mandates. Data on gross domestic products (in billions of U.S. dollars at market exchange rates) were collected from the Energy Information Administration of the U.S. Government.

We also control for firm-level characteristics that influence subsidiary innovation. It is conventional to control for firm size in analyses of innovation output (Cohen and Levin, 1989), although there is no consensus on the expected impact of firm size. Arguments justifying a positive impact propose that size leads to availability of internal funds for innovation, scale economies in research and development, and scope economies due to complementarities between innovation and other activities (marketing and finance) (Cohen and Levin, 1989). Counter-arguments propose loss of managerial control and attenuation of incentives of individual scientists in larger firms, leading to inefficiency in innovation. *Firm size* is operationalized as the log of total assets in year $t - 1$.

We also control for firm leverage. *Firm leverage* indicates the risk orientation of the management, influencing the MNC and subsidiary involvement in innovation. Leverage is measured as the debt/equity ratio of the firm in year $t - 1$. Finally we control for alliances that are an alternative mode through which firms/subsidiaries can gain access to external knowledge resources. Alliances often involve sharing, exchange, and co-development of technology (Gulati and Singh, 1998). Firms with a larger number of alliances will have access to technology possessed by other firms. *Firm alliances* is measured as the total number of alliances entered into by the MNC in the previous 5 years, up to $t - 1$.

Since our study examines subsidiaries over a number of years, we incorporated *year dummies* to control for possible effects of serial correlation. Additionally, in a dynamic study, an issue that may arise is the increase in an industry's propensity to patent over time. We controlled for this by adjusting the patents used to create measures for subsidiary innovation, technological richness and diversity, and knowledge linkages, by dividing them by a factor that accounted for the increase in patenting in the semiconductor industry. We calculated this factor on a yearly basis, with 1981 (our earliest year), as the base. The factor for a particular year was calculated by dividing the total number of semiconductor patents filed in that year by the total number of semiconductor patents filed in 1981. The use of this factor deflates later levels of patenting and controls for increases that may be attributed to an increase in the industry's tendency to patent over time.

Methods

Our dependent variable, subsidiary innovation, is a count variable and takes on only non-negative integer values. Studies involving patents and their citations pose a number of econometric and measurement issues, which primarily stem from the count nature of the dependent variable (Hausman, Hall, and Griliches, 1984). A Poisson model is suggested for dealing with such dependent variables. However, the underlying assumption of the Poisson model is that there is no heterogeneity in the sample. In actual fact, unobserved heterogeneity in the sample may result in a case of overdispersion, a situation where the variance exceeds the mean, causing underestimation of standard errors and an inflation of significance levels. Negative binomial regression models correct for the presence of overdispersion. We follow the approach suggested by Hausman *et al*. (1984) in their analysis of patent data and other researchers when dealing with event count data (Kogut and Chang, 1991) using the negative binomial regression. Since we have cross-sectional time series data involving repeated observations of our set of subsidiaries over time, there may be certain unaccounted subsidiary effects that are fixed over time or vary randomly with time that influence innovation. Fixed effects and random effects models allow us to control for these effects. The Hausman specification test compares the two alternative specifications and allows us to determine the appropriate specification for a particular set of data. We performed this test on our data and the test provided a chi-squared statistic of 128.37 (p-value = 0.0000), supporting the premise that the difference in coefficients was not systematic and that a random effects specification was appropriate.

FINDINGS AND DISCUSSION

The Appendix presents the summary statistics for our sample. Typically overseas subsidiaries have a low level of patenting output; the average number of patents produced by the subsidiary per year was 0.7. Subsidiaries like AT&T Netherlands, Intel Israel, Motorola Switzerland, Texas Instruments (TI) Japan, Italy, and Great Britain had a higher than average innovation output, while subsidiaries of National Semiconductor and Rockwell demonstrated lower than average patenting. An analysis of subsidiary innovation and subsidiary characteristics (knowledge stock, focus, and R&D intensity) reflects strong correlation between these variables, suggesting that the variation in patenting output across subsidiaries and firms may be a function of the subsidiaries role.

Technological richness and diversity of the MNC and the host country demonstrated interesting patterns. MNC richness averaged 1.11, indicating that each firm in our sample generated around 1 percent of the semiconductor patents filed worldwide each year. AT&T and Texas Instruments were substantially more innovative than other firms. Technological diversity of the MNC averaged 0.57, with Rockwell and Motorola demonstrating greater diversity. Host countries with significant knowledge resources were Japan, France, Great Britain, and Germany, while others such as Netherlands, Singapore, Italy, Canada, and Israel had limited knowledge resources. Average diversity of the host country was 0.61—similar to that of the MNC. Typically host countries that were rich in innovation tended to be more diverse. This is borne out by the correlation (0.29) between host country richness and diversity. However, this relationship did not hold within the MNC—rich MNCs were not necessarily more diverse.

The data on knowledge linkages suggest that overseas subsidiaries of U.S. firms are slightly more tied to other subsidiaries in the MNC (an average of 0.26) than to host country firms (0.24). There is a significant correlation (0.49) between subsidiary knowledge linkages with host country and the technological richness of the host country—subsidiaries are more tied to technologically rich host regions. Subsidiary knowledge linkages with the host country are also significantly correlated (0.31) with knowledge linkages with the MNC, suggesting that subsidiaries that have the ability to access and absorb knowledge do so from both the MNC and host country networks. Subsidiaries in our sample reflected a broad spectrum of linkages and the extent of their integration with the MNC network. Some subsidiaries such as ATT China, Motorola Indonesia, and National Semiconductors Mexico demonstrated very limited integration with the MNC as evidenced by knowledge linkages, while others such as Texas Instruments in Great Britain, Japan, and France, Motorola Israel and Japan, and ATT Italy were tightly connected with the MNC. There was an overlap in terms of subsidiaries that demonstrated no integration with the MNC network—the same subsidiaries listed earlier had limited linkages to the host country environment. As far as linkages with the host country were concerned, subsidiaries of Texas Instruments—in Japan, France, Singapore, Italy, and Great Britain—were embedded in the host network, as were Motorola Japan and France and ATT Netherlands.

We present out findings in Table 1, based on negative binomial regression models with random effects.

Results from our baseline model (Model 1) point to the importance of subsidiary R&D in influencing innovation. None of the other subsidiary, firm or host country controls are significant although the overall fit of the model is highly significant at $p < 0.001$. Model 2 presents our findings on the effect of the MNC network on subsidiary innovation. We find strong support for Hypothesis 1a regarding MNC technological richness. Surprisingly, MNC technological diversity and subsidiary linkages to the MNC do not have an impact on subsidiary

Table 1. Negative binomial regression, random effects

Dependent variable: Subsidiary innovation Independent variables		Baseline model Model 1	MNC effects Model 2	Host country effects Model 3	Full model Model 4
MNC knowledge base					
Richness	H1A		1.18***		1.21***
			(0.27)		(0.27)
Diversity	H2A		−1.10		−1.01
			(1.76)		(1.74)
Subsidiary knowledge linkage with MNC	H3A		0.04		−0.02
			(0.10)		(0.11)
Host country knowledge base					
Richness	H1B			0.08	0.09
				(0.07)	(0.07)
Diversity	H2B			2.62*	3.04*
				(1.30)	(1.27)
Subsidiary knowledge linkage with host	H3B			0.13*	0.12*
				(0.05)	(0.06)
Controls					
Subsidiary knowledge stock		−0.01	−0.01	−0.04	−0.03
		(0.02)	(0.02)	(0.02)	(0.02)
Subsidiary focus		0.18	−0.02	0.21	0.02
		(0.19)	(0.20)	(0.19)	(0.20)
Subsidiary R&D		1.15*	1.33***	0.84*	1.08**
		(0.35)	(0.36)	(0.37)	(0.38)
Firm size		−0.26	−1.00*	−0.54	−1.26**
		(0.41)	(0.40)	(0.42)	(0.41)
Firm leverage		−0.0002	−0.002	0.004	0.0007
		(0.007)	(0.007)	(0.007)	(0.007)
Firm alliances		−0.006	−0.01	−0.01	−0.01
		(0.01)	(0.01)	(0.01)	(0.01)
Host country GDP		−0.0002	0.0002	−0.0004	−0.0005
		(0.0001)	(0.0001)	(0.0004)	(0.0004)
Wald statistic		49.30***	71.81***	58.56***	80.00***

$N = 374$; standard errors in parentheses; all models include year dummies
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

innovation. Hypotheses 2a and 3a are not supported. The inclusion of the variables related to the MNC network improves the fit of the model, with the Wald statistic increasing to 71.81.

Model 3 incorporates the effects of the host country network in addition to the controls. Hypotheses 2b and 3b are supported: both technological diversity and knowledge linkages to the host country have a positive and significant impact on innovation. Hypothesis 1b regarding host country richness is not supported. We see an increase in model fit (compared to baseline Model 1), with the Wald statistic at 58.56.

Model 4 presents the results of the comprehensive model. This model mirrors the findings of Models 2 and 3. Hypotheses 1a (MNC technological richness), 2b (technological diversity of host country), and 3b (knowledge linkages with the host country) are supported. The inclusion of both MNC and host country variables led to an increase in the overall fit of the model, with the Wald statistic at 80.00.

Of the controls, subsidiary R&D intensity has a significant positive impact on innovation. The other subsidiary controls including subsidiary focus and subsidiary knowledge stock are not significant. Firm size has a significant and negative impact on subsidiary innovation in Models 2 and 4. These results corroborate Almeida *et al.*'s (2003) finding that as semiconductor firms grow larger they are less likely to exploit external knowledge for innovations. Our other firm-level controls including leverage, alliances, and host country GDP are not significant. The lack of significance of the GDP variable may be driven by the fact that it is highly correlated with all the host country network variables, country richness (0.96), country diversity (0.34), and subsidiary linkages with host (0.46).

Discussion

Our findings illustrate the importance of the MNC and the host country networks to subsidiary innovation within the semiconductor industry. Although past research has highlighted the importance of innovation in this industry and also the relevance of these environments separately, our study suggests the need for considering the dual networks and the relative roles they play. This paper also highlights the conditions under which these networks matter to the innovative performance of subsidiaries and hence MNCs.

An important contribution of this paper is the exploration of firm heterogeneity—in this case, an exploration of the factors underlying differential innovative ability in MNC subsidiaries. Our analysis points to the dual effects of the corporate context and the geographic context, in influencing subsidiary innovation. The paper offers some insights as to why (a) subsidiaries of the same firm, in different locations, or (b) subsidiaries of different firms in the same location may develop varying capabilities.

Our results present an interesting contrast regarding the effects of the MNC and the host country on subsidiary innovation in the semiconductor industry. A non-intuitive result of this study was the apparently limited role of the MNC on subsidiary innovation. Though subsidiaries in general had slightly more linkages to the MNC than to the host country, these linkages were less likely to result in innovations. A possible explanation for our findings is that for semiconductor MNCs learning oriented subsidiaries are in quest of novel knowledge, and linkages to the MNC may provide redundant knowledge, since these ties are within the same social structure (the MNC). It is therefore linkages to host country knowledge that provide the best inputs for innovation.

Another explanation may lie in the differentiated nature of the modern MNC. The subunits of the MNCs play differentiated roles to optimize the capabilities and efficiencies of the MNC as a whole (Bartlett and Ghoshal, 1989). This is particularly true in the context of the semiconductor industry (Almeida, 1996). This may require that certain subsidiaries play unique roles that may not require integration (as far as technology sourcing) with the rest of the firm. For instance, semiconductor subsidiaries in Europe are often oriented towards the development of analog expertise. R&D activities in this area were usually not carried out anywhere else in the firm. Thus, these subsidiaries may play an important organizational and strategic role in the MNC but may not be dependent on MNC knowledge to enhance their innovative output.

Our analysis also reveals that different characteristics of the MNC and host country positively impact subsidiary innovation. Technological richness of the MNC matters (but not that of the host country), while technological diversity and knowledge linkages matter only in the host country. The finding regarding MNC richness (and the lack of finding regarding knowledge linkages) may suggest that subsidiaries in more innovative MNCs benefit, not so much from better technological inputs from within the MNC, but perhaps more from the underlying organizing principles, systems, and processes that permit the subsidiary to conduct innovation (Kogut and Zander, 1996). The associated lack of support for MNC technological diversity may be related to the previously highlighted fact that subsidiaries in this sample do not look internally to the MNC for novel technological inputs.

In the host country environment, the most innovative subsidiaries appear to have greater knowledge exchanges with the host country and are located in more diverse host environments. Surprisingly, technological richness of the host country does not help innovation. A possible explanation for the lack of significance of host country richness is driven by our measurement of this variable. Host country richness encompasses every semiconductor patent generated by all firms operating in the host country. This operationalization results in geographic areas that span many firms and cover a large number of patents. The magnitude of the host country innovation is demonstrated in the summary statistics, with average host country richness at 4 percent of worldwide patents (contrasted with MNC richness at 1%). Although this magnitude of resources exists within the host country, MNCs may in fact target learning from a much narrower subset of firms in a specific region, with whom they are more likely to exchange knowledge. This would result in greater knowledge linkages, which would positively impact innovation, but not demonstrate support for richness. The importance of technological diversity in the host country may underline the differentiated nature of the MNC, where subsidiaries are engaged in technological exploration through linkages within specialized regions and countries (Archibugi and Pianta, 1992). Thus subsidiaries appear to look externally to the host in their exploration of new technologies.

Our findings point to the conditions under which the MNC and host country networks influence subsidiary innovation in general. Of course, we expect subsidiaries with 'world mandates' (Birkinshaw and Hood, 2000) or those that act as integrators (in the terms of Malnight, 1995) to use the host country and the MNC knowledge resources more effectively in innovation. We expect these 'lead' subsidiaries to have greater knowledge stocks since knowledge stocks reflect prior innovative capabilities and perhaps a greater mandate within the MNC.

To evaluate our expectations we split our sample into two subsamples, based on subsidiary knowledge stock. Subsidiaries in our sample had knowledge stock ranging from 0 to 38 patents, with an average of 2.70 patents. We divided our sample equally among the two subsamples; using a cut-off of one patent, subsidiaries with one or fewer patents (in the previous 5 years) were considered less capable subsidiaries, while those with two or more patents were classified as more capable subsidiaries. We ran our regressions on the two subsamples. Our findings are presented in Table 2.

Model 1a includes subsidiaries with lower knowledge stocks and Model 1b is the regression for those with greater knowledge stocks. As expected, Model 1b demonstrates a better fit with a higher pseudo R^2 (0.17) and a significant LR chi-squared statistic. As regards effects of independent variables, we find only one significant effect in Model 1a. MNC richness has a positive impact on subsidiary innovation. Thus less advanced subsidiaries seem to benefit only from parent capabilities in innovation. Model 1b shows that in the case of more capable subsidiaries MNC technological richness, host country technological richness, and host country diversity and knowledge linkages with the host country have a strong positive impact on innovation. Thus the regressions suggest that lead innovators and more capable subsidiaries are better able to utilize knowledge from the host country though not necessarily from the MNC. We also find that subsidiary R&D is able to influence innovation only in more capable subsidiaries, suggesting that R&D investments are most useful in subsidiaries with established innovative capabilities.

Limitations and extensions

The results of our study also point to some limitations and possibilities for future research. First, as Birkinshaw and Hood (1997) suggest, subsidiary mandates vary and are driven by subsidiary, firm, and host country influences. Our study attempts to control for subsidiary mandates by incorporating

Table 2. Subsidiary role effects

Dependent variable: Subsidiary innovation Independent variables		Limited knowledge stock Less capable subsidiaries Model 1a	Extensive knowledge stock More capable subsidiaries Model 1b
MNC knowledge base			
Richness	H1A	1.14*	1.05***
		(0.54)	(0.25)
Diversity	H2A	−7.12	−2.61
		(4.74)	(1.96)
Subsidiary knowledge linkage with MNC	H3A	0.79	0.05
		(0.46)	(0.11)
Host country knowledge base			
Richness	H1B	−0.13	0.10*
		(0.12)	(0.04)
Diversity	H2B	1.36	4.25**
		(1.33)	(1.62)
Subsidiary knowledge linkage with host	H3B	1.57	0.12*
		(1.76)	(0.05)
Controls			
Subsidiary knowledge stock		—	—
Subsidiary focus		—[a]	0.13
			(0.22)
Subsidiary R&D		0.13	1.06**
		(1.36)	(0.38)
Firm size		−1.76*	−1.16***
		(0.74)	(0.33)
Firm leverage		−0.008	0.004
		(0.02)	(0.007)
Firm alliances		0.005	0.005
		(0.03)	(0.01)
Host country GDP		0.0006	−0.0007*
		(0.0007)	(0.0003)
LR chi-squared		23.09	98.10***
Pseudo R^2		0.11	0.17
N		185	189

Standard errors in parentheses; all models include year dummies; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
Subsidiary knowledge stock was excluded from our runs since we used it to define sample split.
[a] Subsidiary focus was automatically dropped by our data analysis package, STATA, in the runs for Model 1A, due to collinearity.

controls relevant to each of these influences. While these variables do not completely define subsidiary mandates, they do allow us to use our data to gain a partial understanding of the role of the subsidiary. In future research we hope to further understand how different subsidiary strategies and roles impact innovation and evolution.

Second, we use patent citation data to measure knowledge linkages with the host and MNC. Our data reflect and measure the outcomes of linkages, but are unable to point to the underlying mechanisms that enable these knowledge flows. Such mechanisms within the organization may represent structures such as cross-functional teams, the movement of personnel or the creation of a culture that fosters innovation. Within the host country, these mechanisms often take the form of alliances, mobility of experts, and informal conversations (Song, Almeida, and Wu, 2003). In future research, we plan to explore the mechanisms that underlie the knowledge linkages between the subsidiary, the MNC, and the host country, and evaluate the roles and efficacy of each mechanism.

Finally, our study provides some insights into the characteristics of the host country and MNC knowledge networks that impact innovation. Our study cannot identify precisely which types of knowledge are made available to subsidiaries from each network. Some interesting questions relating to the complementarity of knowledge from each source and the simultaneous role of each knowledge source in the evolution of the subsidiary remain on the table. We plan to extend our investigation of MNC subsidiaries and innovation in these directions.

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REFERENCES

Ahuja G. 2000. Collaboration networks, structural holes and innovation: a longitudinal study. *Administrative Science Quarterly* **45**(3): 425–455.

Almeida P. 1996. Knowledge sourcing by foreign multinationals: patent citation analysis in the U.S. semiconductor industry. *Strategic Management Journal*, Winter Special Issue **17**: 155–165.

Almeida P, Kogut B. 1999. The localization of knowledge and the mobility of engineers in regional networks. *Management Science* **45**: 905–917.

Almeida P, Dokko G, Rosenkopf L. 2003. Start-up size and external learning: increasing opportunities and decreasing abilities? *Research Policy* **32**(2): 301–315.

Almeida P, Song J, Grant R. 2002. Are firms superior to markets and alliances? An empirical investigation of cross-border knowledge building. *Organization Science* **13**(2): 147–161.

Andersson U, Forsgren M. 2000. In search of centers of excellence: network embeddedness and subsidiary roles in multinational corporations. *Management International Review* **40**(4): 329–338.

Archibugi D, Pianta M. 1992. Specialization and size of technological activities in industrial countries: the analysis of patent data. *Research Policy* **21**(1): 79–93.

Barney J. 1991. Firm resources and sustained competitive advantage. *Journal of Management* **17**(1): 99–120.

Bartholomew S. 1997. National systems of biotechnology innovation: complex interdependence in the global system. *Journal of International Business Studies* **28**(2): 241–266.

Bartlett C, Ghoshal S. 1989. *Managing across Borders: The Transnational Solution*. Harvard Business School Press: Boston, MA.

Birkinshaw J, Hood N. 1997. An empirical study of development processes of foreign owned subsidiaries in Canada and Scotland. *Management International Review* **37**(4): 339–364.

Birkinshaw J, Hood N. 2000. Characteristics of foreign subsidiaries in industry clusters. *Journal of International Business Studies* **31**(1): 141–154.

Buckley P, Casson M. 1976. *The Future of the Multinational Enterprise*. Macmillan: London.

Cantwell J. 1989. *Technological Innovation and Multinational Corporations*. Basil Blackwell: Oxford.

Caves R. 1971. International corporations: the industrial economics of foreign investment. *Economica* **38**(141): 1–27.

Cohen W, Levin R. 1989. Empirical studies of innovation and market structure. In *Handbook of Industrial Organization*, Vol. 2, Schmalensee R, Willig R (eds). Elsevier: Amsterdam; 1059–1107.

Cohen W, Levinthal D. 1990. Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly* **35**: 128–152.

Dunning J. 1994. Multinational enterprises and the globalization of innovatory capacity. *Research Policy* **23**: 67–89.

Dyer J, Noboeka K. 2000. Creating and managing a high performance knowledge sharing network: the Toyota case. *Strategic Management Journal* **21**(3): 345–367.

Dyer J, Singh S. 1998. The relational view: cooperative strategy and sources of interorganizational competitive advantage. *Academy of Management Review* **23**: 660–679.

Galaskiewicz J, Zaheer A. 1999. Networks of competitive advantage. In *Research in the Sociology of Organizations*, Andrews S, Knoke D (eds). JAI Press: Greenwich, CT; 237–261.

Galunic D, Rodan S. 1998. Resource recombinations in the firm: knowledge structure and the potential for Schumpeterian innovation. *Strategic Management Journal* **19**(12): 1193–1201.

Ghoshal S, Bartlett C. 1990. The multinational corporation as an interorganizational network. *Academy of Management Review* **15**(4): 603–626.

Ghoshal S, Korine H, Szulanski G. 1994. Interunit communications in multinational corporations. *Management Science* **40**(1): 96–111.

Ghoshal S, Nohria N. 1989. Internal differentiation within multinational corporations. *Strategic Management Journal* **10**(4): 323–337.

Granovetter M. 1992. Problems of explanation in economic sociology. In *Networks and Organizations*, Nohria N, Eccles R (eds). Harvard Business School Press: Boston, MA; 25–56.

Grant RM. 1996. Prospering in dynamically-competitive environments: organizational capability as knowledge integration. *Organization Science* **7**: 375–387.

Gulati R. 1999. Network location and learning: the influence of network resources and firm capabilities on alliance formation. *Strategic Management Journal* **20**(5): 397–420.

Gulati R, Nohria N, Zaheer A. 2000. Strategic networks. *Strategic Management Journal*, Special Issue **21**(3): 203–215.

Gulati R, Singh H. 1998. The architecture of co-operation: managing co-ordination costs and appropriation concerns in strategic alliances. *Administrative Science Quarterly* **43**(4): 781–814.

Gupta A, Govindrajan V. 2000. Knowledge flows within multinational corporations. *Strategic Management Journal* **21**(4): 473–496.

Hausman J, Hall B, Griliches Z. 1984. Econometric models for count data with an application to the patents–R&D relationship. *Econometrica* **52**: 909–938.

Hedlund G. 1994. A model of knowledge management and N form corporation. *Strategic Management Journal*, Summer Special Issue **15**: 73–90.

Henderson R, Cockburn I. 1996. Scale, scope and spillovers: the determinants of research productivity in drug discovery. *Rand Journal of Economics* **27**(1): 32–60.

Hymer S. 1976. *The International Operations of National Firms: A Study of Direct Foreign Investment*. MIT Press: Cambridge, MA.

Jaffe A. 1989. Characterizing the technological position of firms with application to quantifying technological opportunity and research spillovers. *Research Policy* **18**(2): 87–98.

Jaffe A, Trajtenberg M, Henderson R. 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. *Quarterly Journal of Economics* **108**: 577–598.

Jarillo J, Martinez J. 1990. Different roles for subsidiaries: the case of multinational corporations in Spain. *Strategic Management Journal* **11**(7): 501–512.

Kogut B, Chang S. 1991. Technological capabilities and Japanese foreign direct investment in the United States. *Review of Economics and Statistics* **73**(3): 401–414.

Kogut B, Zander U. 1992. Knowledge of the firm, combinative capabilities and the replication of technology. *Organization Science* **3**(3): 383–396.

Kogut B, Zander U. 1996. What firms do: coordination, identity, and learning. *Organization Science* **7**: 502–518.

Kuemmerle W. 1997. Building effective R&D capabilities abroad. *Harvard Business Review* **75**(2): 61–70.

Kuemmerle W. 2002. Home base and knowledge management in international ventures. *Journal of Business Venturing* **17**(2): 99–122.

Leonard-Barton D. 1995. *Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation*. Harvard Business School Press: Boston, MA.

Levitt B, March J. 1988. Organizational learning. *Annual Review of Sociology* **14**: 319–340.

Lord D, Ranft A. 2000. Organizational learning about new international markets: exploring internal transfer of local market knowledge. *Journal of International Business Studies* **31**(4): 573–591.

Malnight TW. 1995. Globalization of an ethnocentric firm: an evolutionary perspective. *Strategic Management Journal* **16**(2): 119–141.

March J. 1991. Exploration and exploitation in organizational learning. *Organization Science* **2**: 71–87.

Marshall A. 1920. *Principles of Economics*. Macmillan: London.

McGrath R. 2001. Exploratory learning, innovative capacity, and managerial oversight. *Academy of Management Journal* **44**(1): 118–131.

Mowery D, Oxley J, Silverman B. 1996. Strategic alliances and interfirm knowledge transfer. *Strategic Management Journal*, Winter Special Issue **17**: 77–91.

Nelson R. 1993. *National Innovation Systems: A Comparative Analysis*. Oxford University Press: New York.

Nelson R, Winter S. 1982. *The Evolutionary Theory of the Firm*. Harvard University Press: Cambridge, MA.

Patel P, Pavitt K. 1991. Large firms in production of world's technology. *Journal of International Business Studies* **22**(1): 1–22.

Perlmutter H. 1969. The tortuous evolution of the multinational corporation. *Columbia Journal of World Business* **4**: 9–18.

Porter M. 1990. *The Competitive Advantage of Nations*. Free Press: New York.

Powell W, Koput K, Smith-Doerr L. 1996. Interorganizational collaboration and locus of innovation: networks of learning in biotechnology. *Administrative Science Quarterly* **41**(1): 116–138.

Rogers E, Larsen J. 1984. *Silicon Valley Fever*. Basic Books: New York.

Rosenkopf L, Nerkar A. 2001. Beyond local search: boundary-spanning, exploration, and impact in the optical disk industry. *Strategic Management Journal* **22**(4): 287–306.

Rumelt RP. 1974. *Strategy, Structure and Economic Performance*. Harvard University Press: Boston, MA.

Saxenian A. 1990. Regional networks and the resurgence of Silicon Valley. *California Management Review*, Fall: 39–112.

Saxenian A. 1994. *Regional Advantage*. Harvard University Press: Cambridge, MA.

Shan W, Song J. 1997. Foreign direct investment and the sourcing of technological advantage: evidence from the biotechnology industry. *Journal of International Business Studies* **28**(2): 267–284.

Song J, Almeida P, Wu G. 2003. Learning by hiring: when is mobility more likely to facilitate interfirm knowledge transfer? *Management Science* **49**(4): 351–377.

Sorensen J, Stuart T. 2000. Aging, obsolescence and innovation. *Administrative Science Quarterly* **45**(1): 81–112.

Szulanski G. 1996. Exploring internal stickiness: impediments to the transfer of best practice within the firm. *Strategic Management Journal*, Winter Special Issue **17**: 27–44.

Turner M, Fauconnier G. 1997. A mechanism of creativity. *Poetics Today* **20**(4): 397–418.

U.S. Department of Commerce. 1992. *Technology Profile Report: Semiconductors*. Patent and Trademark Office, Department of Commerce, Washington, DC.

Von Hippel E. 1988. *Sources of Innovation*. Oxford University Press: New York.

Westney E. 1993. Country patterns in R&D organization: the United States and Japan. In *Country Competitiveness: Technology and the Organizing of Work*, Kogut B (ed). Oxford University Press: New York; 36–53.

Zander I. 1997. Technological diversification in the multinational corporation: historical trends and future prospects. *Research Policy* **26**(2): 209–227.

Zander I, Solvell O. 2000. Cross border innovation in the multinational corporation: a research agenda. *International Studies of Organization and Management* **30**(2): 44–67.

APPENDIX: SUMMARY STATISTICS

Sr no.	Variable	Mean	Std Dev	1	2	3	4	5	6	7	8	9	10	11	12	13
1	*Subsidiary innovation MNC*	0.70	1.37	1.00												
2	Richness	1.11	0.63	0.15	1.00											
3	Diversity	0.57	0.08	0.11	−0.05	1.00										
4	Knowledge linkage	0.26	0.61	0.31	0.21	0.10	1.00									
	Host country															
5	Richness	4.15	7.49	0.28	−0.05	0.05	0.15	1.00								
6	Diversity	0.61	0.15	0.17	−0.03	0.03	0.07	0.29	1.00							
7	Knowledge linkage	0.24	1.13	0.56	0.09	0.06	0.31	0.49	0.12	1.00						
	Controls															
8	Subsidiary knowl. stock	2.70	4.50	0.59	0.16	0.11	0.38	0.28	0.19	0.63	1.00					
9	Subsidiary focus	0.05	0.24	0.31	0.06	0.06	0.28	0.04	0.08	0.15	0.32	1.00				
10	Subsidiary R&D	0.08	0.21	0.30	−0.22	−0.02	0.24	0.15	0.10	0.25	0.27	0.39	1.00			
11	Firm size	3.86	0.60	−0.14	0.57	−0.44	0.02	−0.14	−0.01	−0.06	−0.13	−0.09	−0.29	1.00		
12	Firm leverage	32.16	21.75	−0.09	0.42	−0.63	−0.02	−0.10	−0.02	−0.03	−0.05	−0.05	−0.11	0.78	1.00	
13	Firm alliances	20.21	10.67	0.11	−0.002	−0.15	0.06	0.05	−0.06	0.05	0.08	0.02	0.03	−0.16	−0.17	1.00
14	Host country GDP	1040.70	1285.10	0.26	−0.04	0.03	0.14	0.96	0.34	0.46	0.27	0.04	0.13	−0.12	−0.08	0.07