Are Firms Superior to Alliances and Markets? An Empirical Test of Cross-Border Knowledge Building

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Abstract

Are multinational corporations (MNCs) superior to strategic alliances and markets in facilitating the flow of knowledge across borders? If so, what are the sources of this superiority? Despite their central importance to the theory and practice of international management, these questions have not been directly tested. Our paper seeks to address this gap in empirical research.

Drawing upon recent research on multinational corporations and the knowledge-based view of the firm, we develop hypotheses regarding the relative superiority of alternative institutional arrangements as regards cross-border knowledge building. Analysis of patent citations by semiconductor companies points to the superiority of multinational firms over both alliances and markets in cross-border knowledge building. Interviews with engineers and managers in MNCs point to the intertwining of codified and tacit knowledge and; therefore, the need for both formal and informal mechanisms for successful knowledge building. Our findings suggest that the superiority of MNCs stems from the firms' ability to use multiple mechanisms of knowledge transfer flexibly and simultaneously to move, integrate, and develop technical knowledge. Our research, therefore, suggests that the challenge of knowledge management for MNCs extends beyond the creation of international information systems, to the design of organizational structures, systems, and culture capable of supporting the flow of knowledge.

(*Knowledge*; *Multinational Corporations*; *Strategic Alliances*; *International*)

1. Introduction

Multinational corporations (henceforth referred to as MNCs) play a central role in transferring technology and other forms of knowledge between countries. Indeed, the view that firms are superior to markets in moving knowledge across national borders is a key foundation for the theory of the MNC. Yet, despite a broad consensus concerning the importance of MNCs in cross-border knowledge flows, there is little empirical evidence of the effectiveness of these corporations, as compared with alternative economic institutions in transferring knowledge between countries. The primary goal of our paper is to investigate the roles of alternative institutional forms in knowledge transfer and development, by systematically testing the hypothesis that firms are superior conduits for cross-border knowledge flows.

Our study takes account of several recent developments in the theory of international business and the knowledge-based theory of the firm. In particular, we recognize that creating value through international knowledge management is not simply about cross-border transfers of technology but also about the related process of knowledge development, which includes knowledge integration. We use the term "knowledge building" to refer to these joint processes. Secondly, we investigate the effectiveness of the MNC in managing international knowledge flows by comparing MNCs with international strategic alliances and market contracts.

We begin by reviewing the role of knowledge in the theory of the MNC. The existing literature provides the basis for some initial insights concerning the role of alternative institutional forms in the movement and development of knowledge across national borders. Based on these insights, we generate hypotheses concerning the relative effectiveness of firms, alliances and markets as conduits for cross-border knowledge building. Patent citation data from the world semiconductor industry are used to test these hypotheses. To help interpret and explain our results, we introduce our findings from interviews with managers and engineers.

1047-7039/02/1302/0147/$05.00
1526-5455 electronic ISSN

2. Theory and Hypotheses Development

2.1. The MNC as a Knowledge Network

The idea that foreign direct investment is driven by a firm's knowledge assets can be traced back to the pioneering work of Hymer (1959) and the subsequent developments by Caves (1971), Buckley and Casson (1976), Teece (1986), and others. The process by which MNCs create value from knowledge was initially conceptualized as a linear sequence: Knowledge was created in the firm's home base and was then diffused worldwide in the form of new products and processes. Knowledge transfer tended to be internalized within the firm to avoid the transaction costs associated with market contracts in knowledge assets. We refer to this characterization of knowledge creation and transfer as the "knowledge diffusion" model of the MNC.

During the last decade, this conventional view of how the MNC creates value from knowledge has evolved considerably as a result of theoretical and empirical research into international firms. We now recognize that knowledge creation and development occurs not only at the home base, but in all of a firm's locations. 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 being generated continuously, in all parts of a company. The internationalization of research and development (R&D) (Mansfield et al. 1979, Dunning 1994) is part of the more general geographical diffusion of knowledge development among MNCs—a trend that has been encouraged by organizational changes within MNCs, especially the relocation overseas of divisional headquarters (Forsgren et al. 1995) and the emergence of dispersed "centers of excellence" (Moore and Birkinshaw 1998). Geographical distribution of knowledge creation is reinforced by the fact that knowledge generation is not restricted to the research lab. Organizational knowledge extends beyond scientific and technical knowledge to embrace every function of the firm and the whole range of managerial and operational processes with the implication that know-how is generated in all productive activities.

Second, we now recognize that a firm's stock of knowledge is grown not only by internal knowledge creation, but also through knowledge acquisition that includes both internal learning (learning by doing) and external learning. Such external learning is a potent source of value creation for MNCs. Common to Marshall's (1920) "industrial districts" and Porter's (1990) localized industry "clusters" is the idea that industry-specific knowledge develops in geographically concentrated locations. This phenomenon is true not only of traditional, craft-based industries, but also of high-technology industries (Saxenian 1990, Almeida and Kogut 1999). An important advantage of the MNC is its ability to access local knowledge in multiple locations. Almeida (1996) shows that the United States subsidiaries of foreign MNCs draw heavily upon the technology of local companies. Shan and Song (1997) find 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.

Third, 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 shows that if the capacity of the recipient organization to absorb new knowledge (absorptive capacity) is a function of that recipient's knowledge base, then the use of knowledge cannot be separated from its creation. Hence, the ability of an MNC to transfer knowledge from its home base to its overseas subsidiaries depends, inter alia, upon the extent to which those overseas subsidiaries are themselves engaged in knowledge development.

This view of the MNC as an international network that creates, accesses, integrates, and applies knowledge in multiple locations provides a much richer view of the processes through which MNCs create value from knowledge. It also means that these processes of value are much more complex than recognized by prior conceptualizations of the international firm. Thus, in outlining their "innovation network model" of the MNC, Ostry and Gestrin (1993) point to a "symbiotic relationship between technology diffusion and technology creation" that involves "numerous feedback loops within the system." (*ibid*: 12). Thus, the fundamental feature of the international movement of knowledge in MNCs is not so much the *diffusion* of knowledge from the units that specialize in knowledge creation to those that specialize in knowledge application, but a much more complex process where units are engaged simultaneously and interactively in both creation and application. The challenge of managing knowledge, therefore, involves not only its transfer but also its development through the combination of the transferred knowledge with the recipient's existing knowledge. We refer to this process as knowledge *building*.[1]

2.2. Alternative Institutional Arrangements for Knowledge Building

The role of the MNC in knowledge building has stimulated research into the processes through which knowledge is managed by these organizations. This research has directed attention to the importance of informal and lateral structures and systems. Ghoshal et al. (1994) identify the important role of interpersonal networks among the subsidiary managers of Philips and Matsushita, while Gupta and Govindarajan (2000) also show how informal mechanisms promote knowledge flows within MNCs. Differentiation between the MNC country subsidiaries also appears to be conducive to knowledge creation. Zander (1997) points to the tendency for overseas subsidiaries to specialize in developing particular technologies, while Nobel and Birkinshaw (1998) show that differentiated roles of international R&D units are associated with differentiated control and communication structures.

These studies give us a much fuller picture of how MNCs create and transfer knowledge and the organizational factors that determine the effectiveness and efficiency of these processes. At the same time, they do not address one of the most fundamental aspects of the international business theory. If, and to what extent, are multinational firms superior to alternative governance structures in promoting cross-border knowledge flows? Transaction cost economics points to the sources of the market failure in knowledge transactions, while the emerging "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). Nevertheless, we know that, despite the inherent advantages of firms in the production and deployment of knowledge, knowledge tends to be "sticky" within firms (Szulanski 1996) and the costs of transferring it overseas are substantial (Teece 1977).

The challenges faced by MNCs in facilitating the flow of knowledge across borders calls to question the relative efficiency and effectiveness of other institutions in facilitating cross-border knowledge flows. Teece (1992) observes that strategic alliances, or the "constellations of agreements characterized by the commitment of two or more firms to reach common goals entailing the pooling of their resources and activities" (p. 19), have become increasingly characteristic of organizational arrangements in fast-paced, technology-intensive industries. If collaborative relationships permit firms to engage in repeated games to achieve mutual adjustment over time and to build trust, alliances can offer many of the same advantages as individual firms in overcoming the transaction costs associated with arms-length contracting between independent firms (Eisenhardt and Schoonhoven 1996, Powell 1990, Hagedoorn and Narula 1996). In the case of cross-border knowledge flows, alliances between independent firms may be capable of similar levels of cooperation in the transfer and development of knowledge as between separate units of the single company, while making available a breadth of knowledge that the single company can not hope to match (Hagedoorn and Narula 1996). Moreover, alliances may be capable of "avoiding the liabilities of the full integration solution . . . that can impair the autonomy so necessary for aspects of the innovation process to proceed." (Teece 1992, p. 19). Also, licenses have been shown to be useful instruments for cross-border technology transfer, though their success has been shown to vary with the experience of the firms involved (Contractor, 1998). Our goal is to examine the comparative performance of these alternative governance structures—firms, markets, and alliances—as regards the process of knowledge building across borders.

2.3. Hypotheses

Received theory offers strong grounds for supposing that firms are more efficient and effective institutions for cross-border knowledge movement than markets. Market failure in knowledge transactions is widely acknowledged (Arrow 1962, Nooteboom 1996), the fundamental problem being the inalienability of most forms of knowledge (Choi et al. 1998). Transaction cost explanations of the potential advantages of firms over markets in managing knowledge have been supplemented by recognition of the role of the firm as a knowledge-processing institution. Once we acknowledge that cross-border knowledge flows are not simply the transfer of existing knowledge to new locations, but involve the creation of new combinations of knowledge, then the potential of the firm to create value extends well beyond transaction cost avoidance. If the essence of the firm is in the "social relationships in which knowledge is embedded . . . that permit the creation, replication, and imitation of technology" (Kogut and Zander 1992, p. 385), then the critical advantage of the firm is the ability to perform knowledge combinations that markets cannot.

The relative performance of firms and markets in transferring knowledge depends upon the characteristics of the knowledge in question. While markets for information and other forms of explicit knowledge fail because of the "public good" characteristic of such knowledge (Arrow 1962), the problems of market contracts for tacit knowledge stem from its "personal" characteristics (Polanyi

1966). Kogut and Zander (1996) show that it is in transferring tacit knowledge that the advantages of the MNC are most apparent: The more complex, less codifiable, and less teachable the knowledge embodied within an innovation, the greater the likelihood that it is transferred overseas by direct investment rather than licensing. The major exception to this picture of market failure relates to those few forms of knowledge where legislation establishes unambiguous property rights, in particular, patents. Even here, however, the limits of patent protection and the complementarity between the knowledge specified in a patent and the know-how required to commercially utilize a patent, means that licensing contracts are unlikely, on their own, to be efficacious mechanism for transferring technical knowledge between different countries. Hence,

HYPOTHESIS 1. *MNCs are superior to the market in building knowledge across borders.*

However, as we noted, firms are not the only institutions capable of avoiding the problems of markets in knowledge transactions. Transaction cost economics offer unambiguous support for the superiority of alliance over pure market contracts in organizing the creation, transfer, and deployment of knowledge (Ring and Van de Ven 1992). Literature on alliances suggests that they offer many of the advantages of firms to the process of knowledge building, including establishment of interorganizational interaction and trust (Hamel 1991, Inkpen 1998). Empirical evidence points to the efficacy of collaboration in moving knowledge between enterprises both in domestic and international settings (Kale and Singh 2000, Anand and Khanna 2000). Hence,

HYPOTHESIS 2. *Alliances are superior to the market in building knowledge across borders.*

The relative performance of strategic alliances and individual firms in effecting cross-border movements of knowledge is less clearcut. Alliances can create conflicting incentives for competition and cooperation, particularly horizontal alliances that bring together competitors (Hamel 1991). At the same time, as pointed out earlier, there is a wealth of evidence that shows that with the necessary trust, harmony of interests, and development of collaborative routines, interfirm alliances can be as effective as individual firms in supporting knowledge flows between countries (Baradacco 1991). Indeed, in some instances, it seems likely that the autonomy and flexibility that strategic alliances permit may enhance knowledge building through stimulating creativity and entrepreneurial initiative.[2]

Nevertheless, given the complexity of cross-border knowledge building in terms of the multiple, complementary processes of knowledge transfer and recombination and the multiple, complementary types of knowledge involved, it seems unlikely that the alliances will be capable of offering the richness and diversity of organizational mechanisms that are available within firms. Research into MNCs has identified the importance of both formal and informal systems of communication and knowledge exchange (Ghoshal et al. 1994, Gupta and Govindarajan 2000); the former requires authority relationships and the latter requires socially embedded reciprocity. Both these organizational characteristics are available to firms but are difficult to establish in collaborative arrangements between firms. We, therefore, predict that in governing the process of knowledge building across borders, firms will outperform markets and alliances. Hence,

HYPOTHESIS 3. *MNCs are superior to alliances in building knowledge across borders.*

2.4. Universality of Hypotheses

Given the diversity of country environments, the different types of knowledge moving across borders, and the heterogeneity of each of these governance mechanisms, how universal are our hypotheses? With regard to the diversity of national environments, a key distinction is likely to be between knowledge building across advanced industrialized countries and knowledge building across countries at different development levels. Research suggests that cultural and economic differences between countries act as barriers to knowledge transfer whether by firm or by alliance (Ostry and Gestrin 1993). However, studies of international alliances suggest that these differences are likely to be a particular problem for interfirm alliances because of their limited administrative and social mechanisms to span differences of culture and language (Parkhe 1991).[3]

With regard to knowledge types, we expect the differences in relative performance of governance mechanisms to be especially strong when tacit knowledge is involved. Of course, as pointed out by Nonaka and Takeuchi (1995), much of the knowledge useful for innovation is indeed tacit and cannot be easily transferred. We have argued that the advantages of firms as conduits for knowledge building tend to increase with the tacitness of knowledge involved. However, we do expect differences in the relative performance of alternative governance mechanisms for more codifiable knowledge as well. Grindley and Teece (1997) argue that even for knowledge, where property rights can be clearly established, alliances and firms have advantages in avoiding the transactions costs associated with market contracts. We believe that because

different types of technical knowledge are complementary, and that because tacit and codifiable knowledge may not always be easily separated, we can formulate our hypotheses with regard to knowledge in general (rather than distinguish between different types of knowledge).

Finally, we also need to acknowledge that within each of our categories—firms, alliances, and market contracts—we can anticipate that the diversity of organizational and human characteristics will result in considerable variation in the international knowledge building performance among different members of the same category. Interfirm differences in communication and knowledge transfer are well-recognized among firms (Ghoshal et al. 1994, Gupta and Govindarajan 2000), while among alliances, the wide diversity in the structural forms and objectives of different alliances may have a significant impact on their performance (Chi 1996, Khanna 1998). Koza and Lewin (1998) argue that a key distinction is between "exploitation alliances" and "exploration alliances." However, the interdependence between exploration and exploitation (e.g., as a result of absorptive capacity) may mitigate the significance of this distinction.

3. Data and Methods

3.1. Research Setting

We selected the semiconductor industry as our research site for two reasons: (1) The industry is a leading example of a knowledge-based industry, and (2) cross-border knowledge transfer and development occurs through all three institutional modes being studied.

In terms of international scope, the industry is preeminently global in nature. The extent of economies of scale require companies to amortize their investment in R&D and manufacturing across the world market. The steepness of learning curves and short product life cycles increase the pressures to exploit new (often undifferentiated) products worldwide. A need for close relationships between semiconductor companies and their customer firms in computers, defense, telecommunications, and consumer electronics has also led to a dispersion of activities. Further, the geographically localized patterns of knowledge development in key clusters such as Silicon Valley, New York-New Jersey, Tokyo-Osaka-Kobe, Taiwan, and Israel has led to location of MNC subsidiaries in these key areas of knowledge development worldwide (Almeida and Kogut 1999). As the geographical dispersion of design and manufacturing has increased, firms are pushed toward accessing and integrating knowledge from multiple locations.

The resulting processes of cross-border knowledge building have occurred through all three institutional mechanisms. The leading companies in the industry are all multinational with a presence in the major consuming markets. All have fabrication plants in major regions of the world (North America, East Asia, and Europe) and most have R&D facilities outside of their home countries. MNCs have also engaged extensively in cross-border alliances as mechanisms for accessing and exploiting not just technical knowledge, but knowledge pertaining to the market and relationships with customers and governments (Mowery et al. 1996). A database of semiconductor alliances that we developed shows nearly a thousand alliances between 1975–1990, involving American, Japanese, European, and Korean firms. Knowledge also moves through market contracts. In semiconductors, patent licenses are a particularly important form of such contracts. During the past 20 years, semiconductor companies have become increasingly active in using patents and using licensing to derive revenues from these knowledge assets. For instance, Texas Instruments earned more than $1.8 billion in royalties during 1986–1993, and a further $1.3 billion during 1994–1995 alone (Grindley and Teece 1997).

3.2. Patent Citations as Indicators of Knowledge Building

Bedeviling all empirical work in knowledge management is the problem of measuring knowledge. For this reason, most empirical studies of innovation have, since the pioneering work of Scherer (1965), concentrated upon a single measure of knowledge output: patents.[4] Patent data have received much attention because they provide detailed information, are systematically compiled, and are available continuously across time (Albert et al. 1991).

Our focus is upon the citations to other patents. We use patent citation data (as opposed to patent counts) to indicate cross-border knowledge building between firms and different units of a firm. The list of citations for each patent is made through a uniform and rigorous process applied by the patent examiner as a representative of the patent office. The patent applicant is obliged by law to specify in the application any and all of "the prior art" of which the applicant is aware. The list of patent citations so compiled is available on the patent document, along with information on the inventor, his or her geographic location, the inventor's company (the "assignee"), and technology types. Thus, it is possible to track knowledge building across people, firms, countries, regions, and time. When a patent resulting from the work of an inventor in country *X*, cites a patent where the inventor was located in country *Y*, we regard such a citation as evidence of cross-border knowledge building.

As indicators of cross-border knowledge building, patent citations suffer from some limitations. First, much

knowledge building does not result in patenting. In general, patents are not especially effective in protecting innovations from imitation. However, in semiconductors, the incentives for patenting innovations are strong, and semiconductor manufacturers are prominent among the ranks of the most prolific filers of patents. IBM, Toshiba, Texas Instrument, AT&T, Hitachi, Motorola, Mitsubishi, NEC, and Fujitsu each have been granted more than 1,000 patents during 1969–1994, and each one received more than 100 patents during 1994 alone (U.S. Department of Commerce 1992, Grindley and Teece 1997).

Second, the argument can be made that patents represent explicit technological knowledge and do not represent tacit knowledge (central to many of our arguments in the theory section). We suggest that while patent documents may themselves represent codified knowledge, patent citations allow us to observe the patterns and end points of the knowledge-building process, regardless of the type of knowledge (codified and/or tacit) involved in the related knowledge-building process.

Studies of innovation suggest that innovative processes generally involve some measure of tacit knowledge (Kogut and Zander 1992). Descriptive and empirical studies of innovation in semiconductor firms support the idea that tacit knowledge plays an important role in industry innovations (Saxenian 1990, Appleyard 1996). Almeida and Kogut (1999) show that patent citations by firms within a region are closely related to the underlying pattern of knowledge flows facilitated via personnel transfer. Hence, we expect that the transfer and application of tacit knowledge, in part, creates innovations that lead to patents.

Further, Mowery et al. (1996) point out that codified knowledge and tacit knowledge flows are closely linked and complementary. Hence, while our arguments deal with tacit knowledge, we use patent citation data to indicate the beginning and endpoints of knowledge building (hence, the likelihood of knowledge building) and subsequently use interview data to uncover the underlying mechanisms and types of knowledge involved.

Finally, not all patent citations represent knowledge building. Some citations may be introduced to distinguish the invention from dissimilar ones, or to protect the firm from litigation. We recognize that such motives introduce noise into our data, but we have no reason to believe that it produces systematic bias in our results. Thus, despite some limitations associated with the use of patent citation data, the uniformity and availability of the data has led to their increasing use in strategic management research to capture knowledge and its flows (Jaffe et al. 1998 and 1993). The U.S. Patent and Trade Office patent database is useful in examining international knowledge flows because (1) Every major player (United States or international) in the semiconductor industry patents extensively under this system for both inventions created in the United States and abroad, and (2) the system of citations is applied uniformly across firms regardless of the MNC national origin.

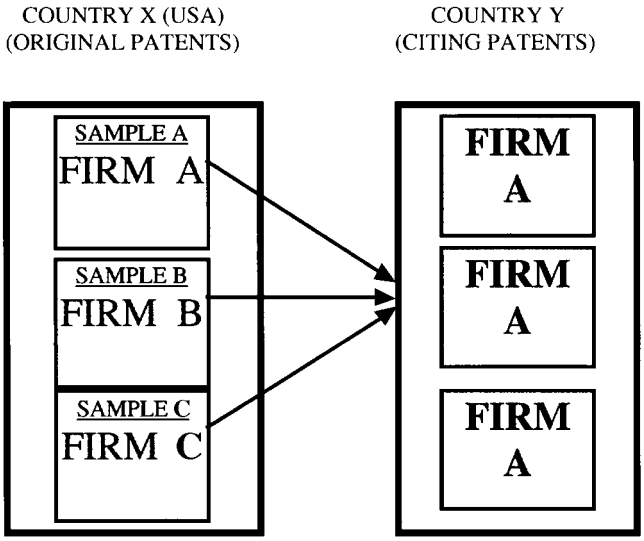
3.3. Samples

We set up samples of matched patents from three sets of firms (see Figure 1).[5]

• Sample A (the MNC Sample) consists of patents belonging to U.S. subsidiaries of foreign MNCs with recorded patenting activity both in the United States and in their home country (Japan, Taiwan, Korea, Singapore, Italy, France, Germany, the Netherlands, and the United Kingdom). There are 21 such MNCs. We selected up to 10 patents (filed before 1991) for each of these firms. The total number of patents selected was 146 (because several of the firms had only a few patents invented in their United States subsidiaries).

• Sample B (the Alliance Sample) consists of patents belonging to the domestic units of United States firms.[6] The United States firms were chosen such that (1) they had a prior strategic alliance with the corresponding MNC

Figure 1 Research Design



Note.

(1) Arrows indicate direction of knowledge building.

(2) Firm B is an alliance partner of Firm A, but does not have a presence in Country Y.

(3) Firm C has neither an alliance with Firm A nor a presence in Country Y.

(4) The original patents are matched by technology and time.

in Sample A and (2) they themselves did not have a subsidiary in the home country of the firm in Sample A. Thus, for example, the first patent in Sample A belongs to Siemens in Silicon Valley and the corresponding first patent from Sample B is from Valid Logic. Valid Logic has an alliance with Siemens in Germany, but does not have a plant in Germany. The patent from Valid Logic is of the same technology class and filed in the same year as the Siemens patent. Thus, for every patent in Sample A, we chose a matching patent in Sample B. Sample B is made up of 146 patents corresponding to those in Sample A.

• Sample C (the Market Sample) consists of patents having the same technology class and filed year as the corresponding patents in Sample A and B, but are assigned to firms in the United States with no formal links to the MNC or its home country. Thus, continuing the example from the previous paragraph, a patent belonging to Zilog Corporation was randomly selected as the first patent in Sample C. The firm is neither allied with Siemens, nor does it have a plant in Germany. Again, the total number of patents in Sample C is 146. Thus, we have three matched samples.

For every patent in each of the three samples, we determined every subsequent patent (up to 1995) that cited these sample patents in the overseas region of the parent company or alliance partner. A subsequent citation is interpreted here as a case of knowledge building upon the original sample patent. The location of the inventor of the citing patent serves to indicate the location of knowledge building. To examine the differences in the likelihood of the cross-border knowledge building among the MNC, alliance, and market samples, we conducted *t*-tests and negative binomial regressions.

3.4. *T*-Test for Likelihood of Knowledge Building

We constructed statistical models for the *t*-tests in two ways. We first modeled a *t*-test at the firm level of analysis as follows:

Let P_A be the frequency probability that a patent from Firm A in Sample A (belonging to the United States subsidiary of an international corporation) is cited by its parent company in its home country. For example, in the case of a patent filed by Siemens' R&D lab in the United States, we observe the likelihood of the patent being cited by Siemens in Germany. Let P_B be the corresponding frequency probabilities that the patents from Firm B (alliance partner of Firm A) is cited by the parent company of Firm A. For example, we observe the likelihood of the Valid Logic patent being cited by Siemens in Germany. P_C is the probability that the patents from Firm C (independent firm in the United States) are cited by the same parent company. For example, we observe the likelihood of a Zilog patent being cited by Siemens in Germany. Assuming binomial distributions, the null hypotheses are

$$H_{o1}\ P_A = P_C, \quad H_{o2}\colon P_B = P_C, \quad H_{o3}\colon P_A = P_B,$$

and the alternate hypotheses are

$$H_{a1}\colon P_A > P_C, \quad H_{2a}\colon P_B > P_C, \quad H_{a3}\colon P_A > P_B,$$

The *t* statistic for the first hypothesis is calculated as

$$t_{AC} = (P_A - P_C)/[(P_A(1 - P_A) + P_C(1 - P_C))/n]^{0.5}.$$

The *t* statistic tests the difference between two independently drawn binomial proportions. A positive significant value of Student's *t* indicates support of the proposition. Thus, in the *t*-test, we tested whether there exists a significant difference in the likelihood of cross-border knowledge building among MNCs, strategic alliances, and markets.

One possible limitation of the above tests is that Sample A uses self-citations (citations from one patent to another one owned by the same firm). The use of self-citations raises two possible problems. First, in spite of legal requirements to cite all known prior art, a firm has incentives not to cite the prior art of another firm, because the citation of prior art can invalidate its patent application (if the new invention is not considered to be a significant extension on the prior art and hence *novel*). The firm must, however, cite some prior art to avoid raising questions by the U.S. Patent and Trade Office. Second, while a firm may minimize citations to another firm's prior art, it has strong incentives to cite its own intellectual property. Firms tend to cite their previous patents because patenting "around" existing patents, can increase their protection and hence value. Also, firms are likely to be most familiar with their own intellectual property and so cite them. Thus, these incentives suggest that self-cites will be increased and cites to other firms decreased. This tendency to increase the number of self-cites (and to avoid citations to the prior art of other firms) is, however, held in check by the patent examiners who determine whether any cite submitted by the firm is indeed prior art or whether any other firm's prior art is improperly excluded. Hence, prior research (Rosenkopf and Nerkar 2001, Sorenson and Stuart 2000) has used self-citations to gauge intrafirm knowledge flows.

However, to deal with the possible self-citation bias, we also conduct an additional *t*-test at the regional level. For example, the number of citations by Siemens in Germany of patents from its United States subsidiary could be influenced by the motivation for the firm to cite itself more often than necessary. We, therefore, define three regions according to the national origin of the MNCs being studied—Japan, Europe, and the rest of Asia (Taiwan,

Korea, and Singapore). Thus, if the patent in Sample A belongs to Siemens, a successful case of cross-border knowledge transfer within the firm is indicated whenever the patent is cited anywhere in Europe. The knowledge transfer is interpreted to have taken place in two stages—first to Germany by Siemens and then regionally in Europe. Correspondingly, for Sample B a citation by any European firm indicates knowledge transfer through the prevailing alliance to Siemens in Germany, followed by regional diffusion. For Sample C, a citation within Europe indicates knowledge transfer through the market. For all three samples, to remove any possible bias because of self-citations, we omitted citations by the parent firm.

3.5. Negative Binomial Regressions

A critical aspect of our empirical analysis is the matching of the patents in Samples B and C to the patents in Sample A. No matter how carefully this matching is done, it is likely that the number of citations to each patent would reflect the influence of other factors. To control factors that may influence the likelihood or the magnitude of the cross-border knowledge building, we conducted a negative binomial regression, following the approach of Hausman et al. (1984) on patent counts. As an extension of the Poisson regression, a negative binomial regression is used to estimate models of occurrences (counts) of an event when the event has extra-Poisson variation in the form of overdispersion. In our negative binomial models, the probability that the number of patent citations will occur n times (with $n = 0, 1, 2, \ldots$) in the first five years of the application is as follows:

$$\text{Prob}\ (Y = yj) = e^{-\lambda_j}\lambda_j^{Yj}/Y_j!\ \text{Where}\ \lambda_j = \exp\ (\Sigma B_i X_{ij})\exp\ (\mu_j)\ \text{and}\ e^{\mu j} \sim \text{Gamma}\ (1/\alpha, 1/\alpha),$$

for observed counts of patent citations Y_j with covariates X_i for the jth patent.

In the negative binomial model that we specify above, μ_j is an unobserved, omitted variable, and $e^{\mu j}$ follows a gamma distribution with mean 1 and variance α as the overdispersion parameter. The larger α is the greater the overdispersion. For estimations of the negative binomial regressions, we used STATA software. To test whether MNCs and alliances offer superior mechanisms for cross-border knowledge building to markets (Hypotheses 1 and 2), we combined Samples A, B, and C and introduced dummy variables for MNC patents (Sample A) and alliance patents (Sample B). To test the performance of firms relative to alliances (Hypothesis 3), we combined Samples A and B only, and introduced MNC patents (Sample A) as a dummy variable.

In addition to these key variables, we added control variables that were created at both patent and parent company levels. At the patent level, to take account of the differences in citations that might result from differences in the quality or the importance of individual patents, we introduced the total number of patent citations by other firms as an independent variable. The likelihood of the cross-border knowledge building may be different in terms of the nature of technologies embedded in each patent, so we added a dummy for design-related patents. In addition, to take account of secular influences on the propensity to cite different parents, we introduced the application year of the patent as an independent variable.

At the parent-firm level, to control interfirm differences in technological capabilities or the propensity to file patents, we added the cumulative number of semiconductor-related patents filed by each parent company for the first five years after the patent application year. We expect that the more patents the parent company files, the more likely the company is to cite patents in our samples. Finally, to control for regional differences in the likelihood of cross-border knowledge building, we added a dummy for Japan.

4. Results and Discussion

4.1. Findings

We first report the results of t-tests in Table 1. At the firm level, the t-tests for all three hypotheses are positive and significant. We found that the MNC offers the most effective institutional arrangement for building knowledge across borders. Alliances, while inferior to the firm, are superior to the market in their knowledge-building ability. Findings from the regional-level t-tests also provided support for Hypotheses 1 and 3, indicating the superiority of MNCs to both market contracts and alliances, but not for the superiority of alliances over the market.

The results of the negative binomial regressions are shown in Table 2 with descriptive statistics and a correlation matrix in Table 3. In line with our findings from t-tests, the results are supportive of Hypotheses 1 through 3. With regard to Hypotheses 1 and 2, dummy variables for MNC patents and alliance patents were both positive and significant in Model 1 of Table 2. With regard to Hypothesis 3, in Model 2 (that combined MNC and alliance patents), the dummy variable for MNC patents was positive and significant, suggesting that MNCs are more effective arrangements for cross-border knowledge building than alliances.

Regarding the control variables, the number of patent citations by other firms in the first five years of the application of the patent was highly significant and positive. This result confirms that higher quality patents are more

Table 1 *T*-Test Results

(A) Firm-Level Analysis of International Knowledge Transfer

Hypothesis	Sample A (Patents Filed by MNC R&D Lab in the United States)	Sample B (Patents Filed by Alliance Partners in the United States)	Sample C (Patents Filed by Control Firms in the United States)	*T*-value
Hypothesis 1 (MNC vs. market)	0.4726 (0.1618)	0	0.0410 (0.0164)	2.67***
Hypothesis 2 (Alliance vs. market)	0	0.1164 (0.0370)	0.0410 (0.0164)	1.93*
Hypothesis 3 (MNC vs. alliance)	0.4726 (0.1618)	0.1164 (0.0370)	0	2.16**

(B) Regional-Level Analysis of International Knowledge Transfer

Hypothesis	Sample A (Patents Filed by MNC R&D Lab in the United States	Sample B (Patents Filed by Alliance Partners)	Sample C (Patents Filed by Control Firms)	*T*-value
Hypothesis 1 (MNC vs. market)	1.3082 (0.2403)	0	0.8013 (0.1991)	1.95**
Hypothesis 2 (Alliance vs. market)	0	0.6575 (0.1261)	0.8013 (0.1991)	−0.64
Hypothesis 3 (MNC vs. alliance)	1.3082 (0.2403)	0.6575 (0.1261)	0	2.65***

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Note.

(1) Number of observations for each sample is 146.

(2) Numbers indicate mean value of matching citations per observation.

(3) Numbers in parenthesis are standard errors.

likely to be cited abroad. Among other patent-level control variables, the patent application year was also significant in both Models 1 and 2. The negative sign of the application year suggests that patents that were filed in the early years of our investigation period tend to be cited more frequently than recently filed patents. For the parent firm-level control variables, we found a positive and significant effect of the number of patents filed by the parent company for the first five years after the application year on the number of citations of the patent. We did not have a significant finding on the effect of design-related patents (as opposed to manufacturing-related patents) on the count of patent citations and the results did not indicate differences in terms of the region of location of the parent company.

4.2. Discussion and Further Evidence

The statistical analysis based on patent citation data provides broad support for our hypotheses concerning the superiority of the MNC as a conduit for cross-border knowledge building. Both sets of *t*-tests as well as the regression analysis support the hypotheses regarding MNC superiority over alliances and the market.

The support for Hypothesis 2, regarding the superiority of alliances over the market, was weaker than Hypotheses 1 and 3. The reason for these weaker findings may pertain to the fact that the conceptual (and practical) dividing line may be blurred between alliances and the market. The practical difficulties in separating alliances from contracts were reflected in the coding of our data. Any extended (beyond five years) or broad (involving multiple patents or broad movement of personnel) licensing agreement was classified as an alliance. Other licensing agreements were coded as market contracts. To assess whether these broad and extended licensing agreements, indeed, acted like other alliances, we ran a *t*-test comparing these (licensing) agreements with other alliances (with respect to their relationship to knowledge building). We did not find any significant differences between the two categories, suggesting that our coding scheme (that included long-term licensing agreements in the alliance category) may not have driven the weaker support for Hypothesis 2.

The above discussion also highlights the fact that the category of alliances covers a broad range of institutional arrangements. These include extended licensing agreements, noncontrolling equity positions, joint ventures and other joint manufacturing, design, and marketing activities. Indeed, this points to the possibility of large intra-category variation in the extent to which various types of alliances facilitate knowledge building. In the case of alliances, recent studies (e.g., Anand and Khanna 2000)

Table 2 Results from Negative Binomial Regressions

Variables	Model 1 Full dataset (Samples A, B, and C)	Model 2 MNC patents and alliance patents only (Samples A and B)
MNC patent dummy (MNC)	3.2578*** (0.9748)	0.6634* (0.3508)
Alliance patent dummy (alliance)	2.5882** (0.9987)	0
Number of patent citations in first five years (total cite)	0.1769*** (0.0156)	0.1749*** (0.0158)
Dummy for design patents (design)	−0.2152 (0.3266)	−0.2784 (0.3295)
Application year (year)	−0.1180** (0.0474)	−0.1127** (0.0485)
Number of patents filed by the parent company for the first five years after the application year (total patent)	0.0005** (0.0002)	0.0004* (0.0002)
Dummy for Japanese parent firms (Japan)	−0.2073 (0.3950)	−0.0878 (0.4031)
Pseudo R^2	0.3524	0.3035
Log likelihood	−84.3403	−79.9986

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Note.

(1) Dependent variable is the number of patent citations by the parent company in the first five years after the patent application.

(2) Standard errors are in parentheses.

have pointed to the fact that different types of alliances may lead to varying opportunities to learn. Therefore, we split our broad category of alliances along two dimensions: upstream vs. downstream alliances (because R&D and manufacturing may lead to greater opportunities for knowledge building).

We conducted *t*-tests to examine whether differences in alliance type would impact the likelihood of interfirm cross-border knowledge building. We did not find any significant differences. We also attempted to evaluate whether there was any difference in performance between those alliances that were structurally closer to firms and those that were structurally closer to markets. Thus, we split our sample into (1) joint ventures and joint development (hierarchy-like alliances) and (2) other alliances (including long-term licensing agreements that are structurally closer to markets). The *t*-tests did not reveal any significant differences in the extent to which the two categories of alliances facilitated knowledge building across borders.

4.3. Interpretation of Patent Findings

The patent analysis provided support for our hypotheses that rested upon the presumed advantages of MNCs in terms of both avoiding the transaction costs of markets and providing mechanisms for knowledge transfer and development that markets and alliances are unable to match. Yet, on the basis of our patent citation data, we could say nothing about the precise identity and operation of these mechanisms.

Although other studies have investigated knowledge transfer within MNCs, few have discussed the broader issue of knowledge building, nor have they made comparisons between alternative institutional arrangements as regards to the process of cross-border knowledge building. Hence, to interpret the statistical results and understand *why* international corporations were more effective than cross-border alliances or market contracts, we elicited the views of the individuals who were directly involved in the knowledge-building process.

We conducted telephone interviews at eight companies—Philips, Siemens, National Semiconductors, Fujitsu, Texas Instruments (TI), IBM, Intel, and Samsung—with two levels of employees.[7] To gain direct input from the front-line personnel engaged in cross-border knowledge building, we contacted a sample of the engineers identified as "inventors" in patent documents (in some cases, these individuals referred us to colleagues). To gain a management-level perspective of the cross-border knowledge processes, we spoke to design managers and directors of technology development. The semistructured interviews (usually with two to three experts at each level) concentrated upon four areas: the processes of international knowledge management, the types of knowledge being managed, the mechanisms for knowledge transfer, and the relative advantages of various institutional arrangements. A summary of our interview findings and how they pertain to our patent results is provided in Figure 2.

Knowledge Management Processes. Interviews with managers confirmed the emphasis that we placed on knowledge building as opposed to pure knowledge transfer. Siemens, Philips, Fujitsu, and National Semiconductor all noted that the development of multifunctional and "system-on-a-chip" application-specific integrated circuits has greatly increased the need to both transfer and combine chip design skills from multiple locations. The

Table 3 Descriptive Statistics and Correlation Matrix

(1) Summary Statistics

Variables	Mean	Standard Deviation	Minimum	Maximum
Depvar	0.2	0.9663	0	14
MNC	0.3333	0.4723	0	1
Alliance	0.3333	0.4723	0	1
Total cite	3.6666	3.9804	0	30
Year	86.2111	3.9804	77	90
Design	0.7555	0.4305	0	1
Total patent	1047.989	848.9785	7	3,031
Japan	0.5111	0.5008	0	1

(2) Correlation Matrix

Variables	Depvar	MNC	Alliance	Total cite	Year	Design	Total patent	Japan
Depvar	1							
MNC	0.1873*	1						
Alliance	−0.0489	−0.500*	1					
Total cite	0.5470*	0.0771	−0.0138	1				
Year	−0.0208	−0.0063	0.0042	0.0667	1			
Design	−0.0250	0.0000	0.0000	−0.0933	0.0182	1		
Total patent	0.0804	0.0000	0.0000	0.1378*	0.2276*	−0.1596*	1	
Japan	0.0953	0.0000	0.0000	0.1044	−0.0889	−0.0391	0.3862*	1

*$p < 0.05$

Figure 2 Summary of Findings: Patent Analysis and Field Research

Research Mode	Insights	MNCs	Alliances	Market Contracts
Patent Analysis	Extent of cross-border knowledge building differs by institutional arrangement	Superior to alliances and markets	Superior to market (weak support)	Inferior to MNCs and alliances
Field Research				
Knowledge-Management Processes	Knowledge building important Integrating knowledge from diverse locations critical	Facilitates knowledge building; integration through loosely coupled modular designs	Facilitates some knowledge building; less useful for modular approach	Facilitates targeted knowledge transfer only
Knowledge Types	Codified knowledge useful Experience-based tacit knowledge critical for problem solving	Codified knowledge flow through IT systems Further knowledge development requires tacit knowledge	Permits movement of both codified and tacit knowledge though less dependable	Best for transfer of codified knowledge
Knowledge Mechanisms	Wide variety of mechanisms useful; flexibility in use of mechanisms important	Facilitates the flexible use of a wide variety of mechanisms	Often provides multiple mechanisms but limited use of informal ones and provides less flexibility	Fewest mechanisms available

former director of TI's Tokyo R&D lab outlined the lab's role in accessing the knowledge bases of TI's Japanese customers, developing technologies where Japan was particularly strong (notably algorithms for image compression), and linking these technologies with ongoing research in Austin, Texas.

Fujitsu's three-dimensional geometry processor is the result of closely integrated development involving both Fujitsu Laboratories in Japan and Fujitsu Microelectronics, Inc. in San Jose, California. Our interviewees identified the key process as *integrating* specialized knowledge drawn from different locations, and the key to efficient integration is the use of loosely coupled modular designs that permit different individuals and groups to input their knowledge into the chip design. Hitachi told us that a modular architecture facilitated the development of a range of digital signal processing chips combining expertise between Japan and California. Many experts suggested that this modular approach to design is considerably more difficult to implement in alliances.

Types of Knowledge. A critical factor in the knowledge-building process is the codifiability of knowledge: Technical information is often highly codifiable, and its transmission can be reduced to data transfer. Thus, computer-based information systems for transferring electronic data form the backbone of the knowledge management systems for all eight companies.

However, with chip design pushing at the limits of physics, experience, intuition, creativity, and problem solving have become increasingly important. Successful problem solving requires linking with multiple knowledge bases, many of which are intuitive and experience based. The head of technology development at National Semiconductor pointed to the importance of integrating both explicit and tacit knowledge. For Intel, a key characteristic of successful design teams was the dual ability to make full use of computerized design tools and design libraries, while exploring new opportunities by drawing upon the deeply engrained know-how of seasoned engineers and the creativity and persistence of younger team members.

Mechanisms of Knowledge Building. Our research revealed a wide range of media through which knowledge moves between the MNCs national units. All of our interviewees put heavy emphasis on the importance of communicating internationally using information technology (IT). IT initiatives included standardized design tools and file formats, shared databases, common communications software, and design libraries, with users linked by company intranets.

National Semiconductor's head of technology development explained how its integrated design system with common naming conventions, Uniplexed Information and Computing System (UNIX) file structures, and design tools have been driven by the vision of concurrent chip design by geographically separated design teams. All of our interviewees suggested the MNC's ability through its authority structure to ensure internal compatibility of information systems and common software and protocols was an important advantage over strategic alliances or independent companies linked by contracts.

However, the nature of the knowledge building revealed the limitations of IT systems, especially when dealing with experiential know-how. At Siemens, engineers working on optoelectonic components explained that file transfers only worked when supplemented by frequent telephone conversations, videoconferences, and personal visits. National Semiconductor pointed to the importance of companywide desktop videoconferencing facilities and the authority given to individual engineers to make overseas visits without the need for supervisory or budgetary approvals.

Our interviewees confirmed prior research concerning the need for "rich" communication media to overcome the limits of electronic media with regard to complexity of language, flexibility of format, degree of personalization, and the extent of interactivity (Daft and Lengl 1986, Daft and Wiginton 1979). The Siemens engineers emphasized that the value of electronically communicated information depended heavily upon the "credibility" of the knowledge source. Higher levels of trust and the likelihood of continuing collaboration in the future meant that information from colleagues in subsidiaries tended to be more credible than those emanating from alliance partners.

One activity where all of our interviewees agreed that multinational firms held a big advantage over international strategic alliances in the international transfer of personnel. A critical aspect of the linkage between TI's Tokyo and Dallas research facilities was the three to six months that every Japanese researcher spent with TI in Texas.

At Intel, international personnel transfers contributed to internationalizing the company's culture, thereby overcoming some of the language and cultural barriers. Hitachi, Fujitsu, and IBM put considerable emphasis of building collaborative company cultures and behavioral norms that transcended national differences. The engineers at Philips and Siemens and R&D managers at IBM gave considerable weight to the role of the interpersonal networks that employees established during their careers in a company. These networks bore resemblances to some

features of the "communities-of-practice" described by Brown and Duguid (1991).

When intrafirm knowledge transfer within the MNC was compared either to transfer through cross-border alliances or market contracts (e.g., technology licensing), our interviewees pointed to the disadvantages of the last two in terms of their reliance upon lean modes of communication, which do not permit the flow and development of rich and tacit knowledge. MNCs also benefited from the greater flexibility and versatility in the use of mechanisms.

All of the companies had vast experience with alliances and these often (though not always) provided many of the mechanisms needed for knowledge transfer, including mobility of personnel, meetings, e-mail exchange, and other forms of communication. However, several managers in the semiconductor companies expressed reservations over the effectiveness of cross-border knowledge transfer through alliances—knowledge transfer was often slow, erratic, uncertain, and superficial. Finally, engineers suggested, licensing agreements with their narrow scope do not provide the same flexibility or rich social context as firms or even alliances in facilitating knowledge building.

5. Conclusions

Our inquiry into the sources of the superior performance of firms over alternative institutions offers some insights into the analysis of knowledge building. First, recent academic literature has increasingly pointed to the tacitness of knowledge as a reason for the difficulties of international knowledge transfer. The popular press, on the other hand, offers IT as a broad solution to knowledge management problems.

Our interviews with engineers and managers in MNCs point to the intertwining of codified and tacit knowledge and, therefore, the need for both formal and informal mechanisms for successful knowledge building. Every company that we spoke to recognized the need to improve the efficiency of international knowledge transfer and development. Therefore, identifying MNCs superiority in transferring and developing knowledge across borders is but a starting point.

The critical issues for management practice relate to the design and use of these knowledge management systems. Based on field research findings, we argued that the knowledge managing advantages of the MNC lie in its ability to standardize procedures and formats, to administer coordination between national units, develop interpersonal relationships between employees, and create a common culture to facilitate communication and cooperation. The design and choice of different mechanisms of knowledge transfer must take careful account of the nature of the knowledge-management process (e.g., the extent to which it seeks to replicate knowledge, to combine knowledge, or to apply it in a new setting), and the types of knowledge involved (in particular, tacit knowledge).

While firms have made huge strides in the use of IT to transfer information and support communication worldwide, the next level of knowledge management lies in the design and operation of management systems and processes to support this IT backbone. Subsequent research needs to investigate, in greater detail, the design and performance of specific international knowledge management practices ranging from multinational new product development to knowledge transfer mechanisms.

As business globalizes, firm advantages arising from traditional sources (such as the unique access to capital, labor, or markets) can be expected to decline. Correspondingly, a company's ability to develop, access, integrate, and deploy knowledge across its worldwide system is likely to grow more critical. Our research suggests that these challenges of knowledge management for MNCs extend beyond the creation of international information systems, to the design of organizational structures, systems, and culture capable of supporting knowledge building.

Acknowledgments

The authors contributed equally to the paper. The research is funded by a grant from the Carnegie Bosch Foundation. The authors thank participants of seminars at Carnegie Mellon University, Harvard University, the Academy of Management, and the Academy of International Business for their suggestions and comments.

Endnotes

[1]Even cases of knowledge transfer, which appear to be close to pure replication such as the global cloning of the McDonald's system of fast-food restaurants involve significant knowledge building to the extent that the knowledge transferred by McDonald's to its overseas franchisees and joint-venture partners is meshed with their own localized knowledge bases to create new knowledge. The challenge for McDonald's and other MNCs pursuing replication-focused strategies is to recognize that overseas affiliates are engaged in knowledge building and then to foster two-way knowledge flows, so that the knowledge building that occurs in individual location can be recycled back to the home base to stimulate further knowledge building.

[2]In the case of Xerox Corporation and Fuji-Xerox, the successful building by Fuji-Xerox upon the technology acquired from Xerox, and the subsequent building by Xerox upon the technology, product designs and business processes acquired from Fuji-Xerox, probably could not have been achieved if Xerox's Japanese associate was a wholly-owned subsidiary.

[3]International business may also increase the information asymmetry between two companies, thus affecting the choice of institutional arrangement employed to exploit this knowledge across borders.

[4]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 United States patent is granted for an invention that is "useful," "novel," and "nonobvious to a person of ordinary skill in the art" (U.S. Department of Commerce 1992).

[5]We use patent citation data from the complete United States patent database 1971–1995 from Derwent Corporation.

[6]We compiled the announcements of every alliance formed between semiconductor firms between 1980–1995 listed in the weekly publication, *Electronic News.* We recorded the complete range of alliances that a firm undertook with other firms in the industry in which these types included joint ventures (for design or for fabrication), equity arrangements (noncontrolling interest), and marketing, design, fabrication agreements.

[7]Our interview sample overlapped our patent citation sample. Although Philips, Siemens, Fujitsu, and Samsung were members of our "Sample A," National Semiconductor, Texas Instruments, Intel, and IBM were not. Our rationale for including the United States companies within our interview sample was to take advantage of the extensive experiences of these companies in managing cross-border knowledge flows over a long time period. We believe that although the processes and practices of knowledge management may vary internationally and across firms, the basic principles and issues in managing knowledge do not change. However, this is an empirical issue and the interviews of firms from different home countries allowed us to investigate this belief.

References

Albert, M., D. Avery, F. Narin, P. McAllister. 1991. Direct validation of citation counts as indicators of industrially important patents. *Res. Policy* **20**(3) 251–259.

Almeida, P. 1996. Knowledge sourcing by foreign multinationals: Patent citation analysis in the United States semiconductor industry. *Strategic Management J.* **7** 155–165.

——, B. Kogut. 1999. The localization of knowledge and the mobility of engineers in regional networks. *Management Sci.* **45**(7) 905–917.

Anand, B. N., T. Khanna. 2000. Do firms learn to create value? The case of alliances. *Strategic Management J.* **21**(3) 295–315.

Appleyard, M. 1996. How does knowledge flow? Interfirm patterns in the semiconductor industry. *Strategic Management J.* **7** 137–154.

Arrow, K. 1962. Economic welfare and the allocation of resources for invention. National Bureau of Economic Research, *The Rate and Direction of Inventive Activity.* Princeton University Press, Princeton, NJ, 609–625.

Baradacco, J. L. 1991. *The Knowledge Link.* Harvard Business School Press, Boston, MA.

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

Brown, J. S., P. Duguid. 1991. Organizational learning and communities-of-practice: Toward a unified view of working, learning and innovation. *Organ. Sci.* **2** 40–57.

Buckley, P., M. Casson. 1976. *Alternatives to the Multinational Enterprise.* Macmillan, London, U.K.

Caves, R. E. 1971. International corporations: The industrial economics of foreign investment. *Economica* **38** 1–27.

Chi, T. 1996. Performance verifiability and output sharing in collaborative ventures. *Management Sci.* **42** 93–104.

Choi, C. J., M. Raman, O. Ussoltseva. 1998. Knowledge-based exchange: Inalienability and reciprocity. Discussion paper, City University Business School, London, U.K.

Cohen, W., D. Levinthal. 1990. Absorptive capacity: A new perspective on learning and innovation. *Admin. Sci. Quart.* **35** 128–152.

Contractor, F. J. 1998. Modal choice in a world of alliances: Analyzing organizational forms in the international hotel sector. *J. Internat. Bus. Stud.* **29**(2) 325–357

——, R. Lengl. 1986. Organizational information requirements, media richness and structural design. *Management Sci.* **32** 554–571.

——, J. Wiginton. 1979. Language and organization. *Acad. of Management Rev.* **4** 179–191.

Dunning, J. H. 1994. Multinational enterprises and the globalization of innovatory capacity. *Res. Policy* **23** 67–88.

Eisenhardt, K., C. Schoonhoven. 1996. Resource-based view of strategic alliance formation: Strategic and social effects in entrepreneurial firms. *Organ. Sci.* **7** 136–150.

Forsgren, M., U. Holm, J. Johanson. 1995. Divisional headquarters go abroad—A step in the internationalization of the MNC. *J. Management Stud.* **32** 475–491.

Ghoshal, S., H. Korine, G. Szulanski. 1994. Internal communication in multinational corporations. *Management Sci.* **40** 96–110.

Grindley, P. C., D. J. Teece. 1997. Managing intellectual capital: Licensing and cross-licensing in semiconductors and electronics. *California Management Rev.* **39**(2) 8–41.

Gupta, A. K., V. Govindarajan. 2000. Knowledge flows within multinational corporations. *Strategic Management J.* **21** 473–496.

Hagedoorn, J., R. Narula. 1996. Choosing organizational modes of strategic technology partnering: International costs and sectoral differences. *J. Internat. Bus. Stud.* **27** 265–284.

Hamel, G. 1991. Competition for competence and inter-partner learning within international strategic alliances. *Strategic Management J.* **12** 83–103.

Hausman, J., B. Hall, Z. Griliches. 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 the N-form corporation. *Strategic Management J.* **15** 73–90.

Hymer, S. 1959. *The international operations of national firms: A study of direct investment.* Ph.D. dissertation, Massachusetts Institute of Technology, Cambridge, MA.

Inkpen, A. C. 1998. Learning and knowledge acquisition through international strategic alliances. *Acad. of Management Executive* **12**(4) 69–80.

Jaffe, M. Fogarty, B. Banks. 1998. Evidence from patents and patent citations on the impact of NASA and other federal labs. *J. Indust. Econom.* **46**(2) 183–205.

——, M. Trajtenberg, R. Henderson. 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. *Quart. J. Econom.* **108** 577–598.

Kale, P., H. Singh. 2000. Alliance capability and success: A knowledge-based approach. Working paper, The Wharton School, University of Pennsylvania, Philadelphia, PA.

Khanna, T. 1998. The scope of alliances. *Organ. Sci.* **9** 340–355.

Kogut, B., U. Zander. 1992. Knowledge of the firm, combinative capabilities, and the replication of technology. *Organ. Sci.* **3** 383–397.

——, ——. 1996. What firms do: Coordination, identity, and learning. *Organ. Sci.* **7** 502–518.

Koza, M. P., A. Y. Lewin. 1998. The coevolution of strategic alliances. *Organ. Sci.* **9** 255–264.

Mansfield, E., D. Teece, A. Romeo. 1979. Overseas research and development by United States-based firms. *Quart. J. Econom.* **95** 737–750.

March, J. G. 1991. Exploration and exploitation in organizational learning. *Organ. Sci.* **2** 71–87.

Marshall, A. 1920. *Industry and Trade.* Macmillan, London, U.K.

Moore, K., J. Birkinshaw. 1998. Managing knowledge in global service firms: Centers of excellence. *Acad. of Management Executive* **12**(4) 81–92.

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

Nobel, R., J. Birkinshaw. 1998. Innovation in multinational corporations: control and communication patterns in international R&D. *Strategic Management J.* **19** 479–496.

Nonaka, I., H. Takeuchi. 1995. *The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation.* Oxford University Press, New York.

Nooteboom, B. 1996. Transaction costs and technological learning. J. Groenewegen, ed. *Transaction Cost Economics and Beyond.* Kluwer Academic Publishers, Boston, MA, 327–350.

Ostry, S., M. Gestrin. 1993. Foreign direct investment, technology transfer and the innovation-network model. *Transnational Corporations* **2**(3) 7–30.

Parkhe, A. 1991. Interfirm diversity, organizational learning, and longevity in global strategic alliances. *J. Internat. Bus. Stud.* **22** 579–601.

Perlmutter, H. 1969. The tortuous evolution of the multinational corporation. *Columbia J. World Bus.* (April).

Polanyi, Michael. 1966. *The Tacit Dimension.* Anchor Day Books, New York.

Accepted by M. Scott Poole.

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

Powell, W. 1990. Neither market nor hierarchy network forms of organization. B. M. Staw and L. L. Cummings, eds. *Research in Organizational Behavior.* JAI Press, Greenwich, CT, 295–336.

Ring, P. S., A. H. Van de Ven. 1992. Structuring cooperative relationships between organizations. *Strategic Management J.* **13** 483–499.

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

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

Scherer, F. M. 1965. Firm size, market structure, opportunity and the output of patented inventions. *Amer. Econom. Rev.* (December) 1097–1125.

Shan, W., J. Song. 1997. Foreign direct investment and the sourcing of technology advantage: An evidence from the biotechnology industry. *J. Internat. Bus. Stud.* **28** 267–284.

Sorenson, J. B., T. E. Stuart. 2000. Aging, obsolescence and organizational innovation. Forthcoming, *Admin. Sci. Quart.* **45** 81–112.

Szulanski, G. 1996. Exploring internal stickiness: Impediments to the transfer of best practices within the firm. *Strategic Management J.* **17** 27–43.

Teece, D. J. 1977. Technology transfer by multinational firms: The resource cost of transferring technological know-how. *The Econom. J.* **87** 242–261.

——. 1986. Transaction cost economics and multinational enterprise. *J. Econom. Behavior and Organ.* **7** 21–45.

——. 1992. Competition, cooperation, and innovation: Organizational arrangements for regimes of rapid technological progress. *J. Econom. Behavior and Organ.* **18** 118–125

U.S. Department of Commerce, Patent and Trademark Office. 1992. *General Information Concerning Patents.* U.S. Department of Commerce, Washington, D.C.

Zander, I. 1997. Technological diversification in the multinational corporation: Historical evolution and future prospects. *Res. Policy* **26** 209–227.