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Innovation in multinational subsidiaries: The role of knowledge assimilation and subsidiary capabilities

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Abstract

Subsidiaries of multinational firms play an important role in the globalization of innovation, yet we have an incomplete idea of the influences on their innovative activity. Drawing on prior research in international business and strategy, we identify two sets of factors that influence the absorption and utilization of knowledge in multinational corporation subsidiaries: (a) the range of external and internal knowledge sources available; and (b) the subsidiary capabilities associated with knowledge absorption and utilization. We find that knowledge absorbed from the host country is useful to subsidiary innovation. We also find support for the role of subsidiary capabilities: both sourcing capability and combinative capability have a significant influence on the scale and quality of innovation.

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INTRODUCTION

A common focus of research in the field of international business has been the globalization of firms across a wide spectrum of industries, and the strategies adopted by these firms to create a global competitive advantage. One aspect of these strategies involves the globalization of the innovative activities of multinational corporations (MNCs), particularly in high-technology industries (Almeida & Phene, 2004; Frost & Zhou, 2005). After all, a popular perspective of the MNC is that of a globally distributed innovation network, with its success linked to the capacity to assimilate, generate, and integrate knowledge on a worldwide basis (Bartlett & Ghoshal, 1989; Hedlund, 1994). While there has been significant work on knowledge integration within the MNC (Ghoshal, Korine, & Szulanski, 1994; Gupta & Govindrajan, 2000), and in spite of recent contributions to the role played by subsidiaries in MNC innovation (Kotabe, Dunlap-Hinkler, Parente, & Mishra, 2007; Rugman & Verbeke, 2001), the ability of the MNC (and its subsidiaries) to assimilate external knowledge and use it for innovation is incompletely understood. This understanding is important, as recent research suggests that subsidiaries are playing an increasingly important role in MNC innovation (Venaik,

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Midgeley, & Devinney, 2005) and hence the globalization of innovation.

To better understand the process of globalization of innovation in general, and the role played by MNC subsidiaries in particular, our study incorporates: (a) research on the MNC and subsidiaries, primarily from the field of international business; and (b) research in strategic management that provides insights into the absorption of external knowledge and its use in innovation. To understand the factors that influence the scale and quality of innovation in MNC subsidiaries, we identify two sets of determinants in the knowledge creation process of MNC subsidiaries: the set of available external and internal knowledge sources, and the role of subsidiary capabilities in using this knowledge to generate innovations.

Subsidiaries can assimilate knowledge from multiple sources within and outside the MNC.[1] Our study seeks to understand *which* sources of knowledge are most useful to MNC subsidiary innovation. While knowledge assimilation is important, the role of subsidiary capabilities in utilizing and integrating this knowledge is critical to innovative success. The notion of absorptive capacity points to a firm's ability to access and exploit external knowledge (Cohen & Levinthal, 1990). We examine this ability in the context of the subsidiary, and suggest that it could be separated into related but distinct roles of sourcing capability and combinative capability. Our research also explores the effects on subsidiary innovation of the subsidiary's *sourcing capability* (a capability arising from R&D expertise that enables it to assimilate external knowledge) and *combinative capability* (a managerial capability that permits the integration and recombination of knowledge). Thus our paper develops a model of subsidiary innovation to investigate the dual effects of knowledge assimilation and subsidiary capabilities.

Using patent citation data, we test the model using negative binomial regression analysis on panel data of foreign subsidiaries of US semiconductor MNCs. The semiconductor industry is a particularly appropriate setting, since it has a globalized innovation process that does not face pressures for localization of its products. We find that knowledge assimilated from host country firms is useful for innovation. Interestingly, our tests point to the limited role played by the MNC headquarters and other subsidiaries in subsidiary innovation. Our findings suggest that subsidiary capabilities play an important role in influencing the quality and scale of innovative activity.

THEORY AND HYPOTHESES

MNC Subsidiaries

Research on the role of subsidiaries in the MNC has evolved over the years, since the early work by Bartlett and Ghoshal (1989) that used the role of subsidiary strategy and structure as one of the criteria to classify MNCs. Subsequently there has been a surge of interest in the multinational subsidiary and a stream of research that explores subsidiary roles, charters, and mandates (Birkinshaw & Morrison, 1995; Martinez & Jarillo, 1991). Studies have explored the effect of the subsidiary on the MNC's performance by examining the creation of firm-specific advantages (Birkinshaw, Hood, & Jonsson, 1998) through knowledge transfer within the MNC (Gupta & Govindrajan, 2000; Hansen & Lovas, 2004). Given this importance of the subsidiaries to MNC success, researchers are increasingly examining subsidiary performance (Andersson, Forsgren, & Holm, 2002; Feinberg, 2000; Venaik et al., 2005).

One of the areas of subsidiary performance receiving attention in recent years is their role in the innovation system of the MNC. Frost (2001) explores the origins of knowledge utilized by subsidiaries to create technological innovation, and shows that they contribute to an MNC's innovative success. Almeida (1996) finds that subsidiaries of foreign firms in the US actively source knowledge from regional sources and use them for innovation. Almeida and Phene (2004) explain the differences in innovation capability of subsidiaries as a function of knowledge sources available to the subsidiary. A related stream of research focuses on the role of subsidiary capabilities in determining performance. Birkinshaw (1996), in his analysis of multinational subsidiary mandates, finds that the drivers of subsidiary growth are distinctive subsidiary capabilities. Other research (Frost, Birkinshaw, & Ensign, 2002) examines the development of subsidiary capabilities, pointing to a situation where advanced capabilities are found in subsidiaries rather than the headquarters. Frost et al. (2002) indicate that these subsidiary capabilities are heterogeneous, with each subsidiary developing distinct expertise often reflecting regional advantages. Feinberg (2000), in her research on Canadian subsidiaries of US MNCs, finds that subsidiaries with higher levels of R&D

and human capital resources grow more. The cumulative evidence of this research suggests that subsidiary innovation depends both on the knowledge it is able to acquire from external sources and on subsidiary capabilities to absorb and utilize this knowledge. We develop this line of research by examining the effects of various sources of knowledge assimilation and subsidiary capabilities on the scale and quality of subsidiary innovation.

Knowledge Assimilation

Knowledge plays a central role in the process of innovation: it serves both as input and as output. The knowledge needed for innovation may be obtained from a variety of sources. While knowledge developed and embodied within a firm is an important source of competitive advantage (Barney, 1991; Grant, 1996), research in strategy shows that knowledge from outside a firm's boundaries also contributes to its success (Dyer & Singh, 1998; Gulati, 1999). A multinational subsidiary can assimilate knowledge from a set of six exhaustive and mutually exclusive sources. The first three operate under a unified corporate identity: the subsidiary itself (i.e., utilizing own knowledge); MNC headquarters (located in the home country of the MNC); and other MNC subsidiaries (located in other countries). The three sources located outside the firm's boundaries are: other firms in the host country (where the subsidiary is located[2]); other firms in the home country (where the MNC headquarters are located); and firms in other countries. Based on prior research that has focused on the importance of the local regional environment (Almeida, 1996; Ghoshal & Nohria, 1989) and the organizational environment (Almeida & Phene, 2004; Gupta & Govindrajan, 1991) as facilitating knowledge flows within and across organizations, we develop hypotheses on the effects of knowledge assimilation from these sources on the scale and quality of subsidiary innovation.[3]

Knowledge Assimilation from MNC: Headquarters and Other Subsidiaries

The early literature in international strategy viewed subsidiaries as ''appendages'' of the MNC in the case of most Japanese and American firms, or as largely independent entities in the case of European firms (Stopford & Wells, 1972). Recent research views the MNC as a global but differentiated network, and emphasizes the interdependence of subsidiaries with the MNC. This is particularly true in the context of knowledge creation and exchange within the firm. Kogut and Zander (1993) suggest that MNCs are social communities that specialize in the transfer and recombination of knowledge. Similar ideas regarding knowledge transfer within the firm are presented in pioneering research in Perlmutter's (1969) seminal work on the ''geocentric'' firm, and are later captured in Bartlett and Ghoshal's (1989) ''transnational corporation'' and Hedlund's (1994) ''hypermodern heterarchy'' and research on the MNC as a vehicle for integrating knowledge located in different parts of the world (Ghoshal & Bartlett, 1994; Birkinshaw et al., 1998). The underlying notion is that a subsidiary should be able to assimilate knowledge from the headquarters and other subsidiaries by virtue of belonging to this common social community.

We therefore expect the MNC (both headquarters and other subsidiaries) to be a valuable source of knowledge for the subsidiary. What is the effect of knowledge assimilation from the MNC on subsidiary innovation? The presence of a unified organizational context provides a set of processes and routines within the firm that enable the smooth flow of knowledge from different parts of the firm and its utilization. In addition, the boundaries of the firm create a common social structure, with the presence of shared knowledge, values, and assumptions. Tsai (2001) suggests that intra-organizational knowledge transfer between units contributes to the unit's ability to innovate. Consequently a subsidiary can be expected to obtain and effectively utilize relevant knowledge from other parts of the MNC, and this can be expected to enhance its innovativeness. Given the differentiated nature of the MNC network, knowledge from the headquarters and other subsidiaries is expected to encompass a rich diversity.[4] Phene and Almeida (2003) find empirical support for this idea for semiconductor multinational firms, with national subsidiaries of MNCs demonstrating competence in distinct and specialized technologies. Thus significant opportunities exist for cross-fertilization of knowledge within the MNC across the specialized and technologically diversified network (Zander & Solvell, 2000). Consequently, the subsidiary may be able to generate new recombinations from this knowledge pool, thereby increasing the quality of its innovation.

Not all inter-unit linkages within the MNC are alike. Ghoshal et al. (1994) posit that inter-unit linkages within the MNC are of two types: vertical linkages that subsidiaries maintain with the headquarters, and horizontal linkages that connect one subsidiary with another. The strength of these linkages may vary, with the vertical linkages often being stronger and more directly aligned with the organizational structure. In a similar vein, Hansen, Mors, and Lovas (2005) suggest that different subsets of social networks within the organization have differential effects on knowledge sharing. While we expect positive effects of knowledge assimilated from the MNC headquarters' and other subsidiaries, the amount of knowledge absorbed may vary, since theses sources are connected by different lines of communication (horizontal *vs* vertical), and possibly reflect different underlying social networks.

Hypothesis 1a: Knowledge assimilated from MNC headquarters has a positive influence on the scale of subsidiary innovation.

Hypothesis 1b: Knowledge assimilated from MNC headquarters has a positive influence on the quality of subsidiary innovation.

Hypothesis 2a: Knowledge assimilated from other subsidiaries in the MNC has a positive influence on the scale of subsidiary innovation.

Hypothesis 2b: Knowledge assimilated from other subsidiaries in the MNC has a positive influence on the quality of subsidiary innovation.

Knowledge Assimilation from Host Country Firms

Host country firms are also a potential source of knowledge for the subsidiary. The existence of geographically clustered firms points, in part, to localization of knowledge within countries. Firms located in geographically concentrated clusters create competitive advantage through local knowledge exchange that rivals located elsewhere cannot match (Porter, 1998). Further, empirical studies by Almeida (1996) and Frost (2001) show that multinational subsidiaries assimilate knowledge from host country regions. Though firms could assimilate knowledge across geographic distances, proximity enhances the development of complex networks (Almeida & Kogut, 1999; Graham, 1985) by reducing the cost and increasing the frequency of personal contacts (Zucker & Darby, 1998). Evidence suggests that these complex networks emerge as a consequence of the development of social and professional networks within geographic boundaries (Saxenian, 1994). Subsidiaries can thus effectively assimilate knowledge from outside the firm owing to physical proximity and the presence of underlying social networks. While the mechanism for effective knowledge assimilation from within the firm is the social structure that arises from common organizational conditions, knowledge assimilation from host country firms is an outcome of similarity in social structure as a consequence of common geographic or regional conditions. We expect effective knowledge assimilation from the firms in the host country to lead to increased scale of subsidiary innovation.

The national innovation systems perspective suggests that countries develop relatively stable and distinct trajectories of technological specialization (Cantwell, 1989). Thus the knowledge that the MNC possesses (possibly imprinted by home country technology and practices) is likely to be different from the knowledge within the host country. Consequently, there is potential for the subsidiary to use assimilated knowledge from the host country for recombinations with MNC knowledge to increase the quality of innovation. We therefore expect knowledge assimilated from host country firms to increase the quality of subsidiary innovation.

Hypothesis 3a: Knowledge assimilated from other firms in the host country has a positive influence on the scale of subsidiary innovation.

Hypothesis 3b: Knowledge assimilated from other firms in the host country has a positive influence on the quality of subsidiary innovation.

Subsidiary Capabilities and Innovation

While knowledge from both the MNC and host country is critical to innovation, the utilization of this knowledge is dependent on subsidiary capabilities. For instance, Birkinshaw and Hood (2000) suggest that in addition to the important influence of the parent and the local environment in determining subsidiary roles, the influence of the subsidiary management cannot be overlooked. To examine the role played by capabilities of the subsidiary in the innovation process, we apply the construct of absorptive capacity (usually viewed at the firm level) to subsidiaries.

Research on firm innovation and learning has focused on the role of absorptive capacity (Cohen & Levinthal, 1990; Lane & Lubatkin, 1998; Minbaeva, Pedersen, Björkman, Fey, & Park, 2003). Cohen and Levinthal (1990) suggest that absorptive capacity (or the firm's ability to recognize, assimilate and exploit new external information) is critical to its innovative capabilities. They suggest that a firm's investment in basic research enables it to recognize and absorb knowledge external to the firm, and this has led several research studies to subsequently use R&D intensity as a measure of absorptive capacity. However, this measure (and approach) may not fully capture the richness of this multidimensional construct (Lane, Koka, & Pathak, 2006; Zahra & George, 2002). There have been attempts to explore different conceptualizations and determinants of absorptive capacity, such as viewing it as a dyad level relative construct (Lane & Lubatkin, 1998), internal information provisioning (Lenox & King, 2004), or the breadth of firm R&D activities (Nicholls-Nixon & Woo, 2003). Lane, Salk, and Lyles (2001), in their study of learning and performance of international joint ventures, suggest that absorptive capacity can be segmented into its components. Van den Bosch, Volberda, and Boer (1999) demonstrate, through case studies of a group of firms, that absorptive capacity is increased by changes in organizational form and combinative capabilities. Our study attempts to further explore and extend our understanding of the absorptive capacity construct by unpacking it and presenting alternative specifications of the construct. We suggest that the capability to recognize and absorb outside knowledge may be usefully separated from the capability to put this knowledge to new innovative uses. We develop hypotheses about the effects of subsidiary sourcing capability (related to the recognition and absorption of knowledge) and subsidiary combinative capability (related to the integration of this acquired knowledge leading to innovation).

Subsidiary sourcing capability. Subsidiary sourcing capability represents the subsidiary's ability to effectively recognize and absorb knowledge. How do subsidiaries recognize and absorb knowledge? Technical expertise and insights resulting from the investment in R&D may provide an organization with the capability to recognize important knowledge and identify potential sources of this knowledge (Cohen & Levinthal, 1990). Thus the knowledge stock of the subsidiary can be expected to reflect this expertise and serve as an appropriate indicator of sourcing capability. Of course, the mere recognition of the importance of outside knowledge does not necessarily permit a firm to absorb it. The firm must also develop linkages to outside sources of knowledge that act as conduits for knowledge transfer (Dyer & Nobeoka, 2000; Gulati, Nohria, & Zaheer, 2000). The formation of relationships with external organizations (formal and informal) is facilitated by the possession of valuable knowledge, since a firm's knowledge base makes it more attractive to other organizations interested in the acquisition and sharing of knowledge. For instance, Von Hippel (1988) describes how firms use patented knowledge as "bargaining chips" when arriving at inter-firm technology agreements. Almeida (1996) shows that MNC subsidiaries that absorb knowledge are also most likely to share it with other firms. Possession of valuable knowledge permits reciprocity in knowledge exchange, and helps open up channels that facilitate inter-firm knowledge flows, as evidenced by research on technological communities (Rosenkopf, Metui, & George, 2002), alliances (Inkpen & Dinur, 1998), acquisitions (Shan & Song, 1997), and regional clusters (Saxenian, 1994). Thus the capability of the subsidiary to recognize and absorb external knowledge is linked closely to its knowledge stock. We call this capability, which emerges from research knowledge, and permits the recognition and absorption of external knowledge, the sourcing capability of the subsidiary. Sourcing capability plays an important role in subsidiary innovation. By ensuring the availability of new knowledge this capability permits the subsidiary to increase the scale and quality of innovation

Hypothesis 4a: Subsidiary sourcing capability has a positive influence on the scale of subsidiary innovation.

Hypothesis 4b: Subsidiary sourcing capability has a positive influence on the quality of subsidiary innovation.

Subsidiary combinative capability. A subsidiary's sourcing capability may help bring in new knowledge to the subsidiary, but there may be differences across subsidiaries in how this knowledge is utilized. Mudambi and Navarra (2004) find that in recent years MNC subsidiaries are more active in innovation, and have taken on a more creative role. Combinative capability represents this creativity in knowledge management. For value creation through innovation, knowledge absorbed from the outside must be *combined* with subsidiary knowledge and knowledge from other sources (Kogut & Zander, 1992). It was Schumpeter (1934) who first pointed out that innovation takes place by ''carrying out new combinations'' (p 65).

How do these combinations occur? Cohen and Levinthal (1989) highlight the importance of internal communication systems, while Zenger and Lawrence (1989) point out that the ability to communicate knowledge across organizational sub-units depends in part on the prevalence of a shared language and culture. Mere communication of knowledge may not be sufficient to ensure its exploitation. The nature of innovation, and the tacit and complex nature of knowledge, may require that several sub-units interact actively across extended periods of time to develop new products or processes (Westney & Sakakibara, 1986). Hansen (1999) demonstrates that multiple inter-unit linkages within an MNC lead to increased knowledge sharing and transfer. Thus, to facilitate this knowledge-building process, firms must establish intra-organizational mechanisms, processes, and systems to link various sub-units across time (Almeida, Grant, & Song, 1998). Henderson and Clark's (1992) concept of architectural knowledge reinforces this idea, suggesting that a critical feature of innovative ability may be the broader managerial capability to combine or link together components. Thus combinative capability is an internal managerial capability that enhances a subsidiary's innovation by moving knowledge within the firm and integrating knowledge from different sources.

How is combinative capability developed? Chandler (1990) suggests that, in general, capabilities are fairly stable and arise from a firm's unique experiences. Capabilities are shaped by the learning experience and become lodged in routines (Nelson & Winter, 1982). Lorenzoni and Lipparini (1999) explain that the ability to integrate knowledge residing both inside and outside the firm's boundaries is a distinctive organizational capability that develops in an organization over time. Using these arguments in the context of the subsidiary we see combinative capability as a managerial capability related to its experience in combining and exploiting knowledge from different sources. Combinative capability enhances both the scale and quality of subsidiary innovation by utilizing assimilated knowledge better.

Hypothesis 5a: Subsidiary combinative capability has a positive influence on the scale of subsidiary innovation.

Hypothesis 5b: Subsidiary combinative capability has a positive influence on the quality of subsidiary innovation.

DATA AND METHODS

Research Setting

We test our hypotheses in the context of the semiconductor industry. The semiconductor industry is a knowledge-based industry and is populated, in part, by large MNCs with subsidiaries in all three of the major regional bases of the industry: North America, Europe, and Asia. Though the industry has been international since the early 1960s, in the 1980s, 1990s and 2000s every leading company in the industry moved towards much greater internationalization (including international distribution of research, design and fabrication activities). The industry is a particularly unique global industry that serves global customers who may require specific product customization but not necessarily localization of products and services.[5] For many companies, therefore, an important factor driving the dispersion of R&D activities is the desire to be close to sources of knowledge, including leading customers, suppliers, universities, and competitors, thus leading to greater subsidiary innovation. The international character of knowledge development in the industry has led firms to actively source knowledge through their subsidiaries and share this knowledge throughout the MNC (Almeida, 1996). The global dimensions of the semiconductor industry therefore specifically relate to the organization of innovation and supply chain activities. Consequently the industry is less vulnerable to issues of localization, cross-cultural and institutional differences prevalent in some other technology industries.

Sample

Our sample consists of the subsidiaries of US semiconductor firms that have patented with the US Patent Office. US firms patent extensively using the US patent system for innovations created both in the US and abroad. We identified a total of 26 subsidiaries from six US semiconductor firms[6] that engaged in R&D and had patented innovations between 1981 and 1992. Our sample is therefore a convenience sample constrained by data limitations and availability. Though the patents by these firms were limited to the time period indicated, the citations by and to these patents covered the period 1971–1998. We analyzed every patent generated by these subsidiaries in non-US locations (the inventor locations for the patents in our sample were outside the US). The unit of analysis is a subsidiary-year. Each of the 26 subsidiaries was tracked over a 12-year period (1981–1992), bringing the total number of observations in the sample to 240. The actual sample size of 240 is different from 26 (number of subsidiaries) multiplied by 12 (number of years of observations), 312, for two reasons: (a) not all subsidiaries began patenting in 1981 – some subsidiaries, for example Intel Germany, began patenting later (in 1986), and therefore did not contribute 12 years of observations; and (b) the lags built into our regression caused the first observation for each subsidiary to have to be dropped. Patent data were obtained from a database (originally supplied by Derwent Inc.) and from the on-line database LEXIS-NEXIS. Firm-level data were obtained from Compustat.

Patents and Patent Citations

We use patent data to track the scale and quality of innovation of foreign subsidiaries of US multinational firms. We consider patents that are granted by the United States Patent Office: this includes patented innovations created in both US and overseas locations. Since the US is a major market, and design and manufacturing location for semiconductors, US intellectual property rights are considered critical for any firm in the industry, and every major semiconductor firm patents extensively under the US system.

The front page of a patent document has extensive information, useful to the study of innovation and innovative influences. Patent documents allow us to pinpoint an innovation in geographic, technological and temporal space (Trajtenberg, 1990). As in previous studies using patent citation data (Almeida & Kogut, 1999), we use assignee name to identify the MNC, the geographic location (city and country) of the inventor of a patent to establish the location of the invention, and the date of application of the patent to establish the innovation date. The list of patent citations, provided on the front page of the patent document, permits us to infer the scientific and technological influences on a particular invention (Jaffe, Trajtenberg, & Henderson, 1993). 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 citations for each patent is established through a uniform and rigorous process applied by the patent examiner as a representative of the patent office (Albert, Avery, Narin, & McAllister, 1991). We use the list of citations on a given patent belonging to the subsidiary to infer the knowledge assimilation.

There are, of course, a number of limitations to using patent citation data to capture innovation and knowledge assimilation. First, patents reflect codified knowledge but not tacit knowledge (such as that embedded in organizational routines). However, Mowery, Oxley, and Silverman (1996) point out that codified knowledge flows (represented by patents) and tacit knowledge flows are closely linked and complementary. This limitation may also be attenuated, in this study, by its focus on technological knowledge, which is more easily codified and patented than, for instance, organizational knowledge. 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, the nature of competition in the semiconductor industry encourages active patenting of innovations. Every major firm in the semiconductor industry, regardless of national origin, has an extensive patent portfolio (Almeida, 1996). Further, in this study we use patent data to gauge organizational capabilities associated with sourcing and combination of knowledge. Of course, patent data can give us only an indirect indication of these capabilities. 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, Fogarty, & Banks, 1998; Jaffe et al., 1993).

Variable Operationalization

We describe, below, the variables included in our analysis and their operationalization.

Dependent variables. Our two dependent variables – the scale and quality of subsidiary innovation – were constructed by examining the patent portfolio of the subsidiary and the citations received by the portfolio.

Scale of subsidiary innovation This was measured as the number of semiconductor patents applied for by the subsidiary in a given year t. We calculated scale based only on semiconductor patents by using USPTO technology classes.[7] We determined whether patents belonged to a particular subsidiary of an MNC by examining the assignee name (typically the name of the MNC, such as Intel or Texas Instruments) and the geographic location (i.e., country, such as France or Japan) of the inventor, to determine the subsidiary. We used the patent application date of successful patents (or the date that patent was filed with the Patent Office) to indicate the year of innovation.

Quality of subsidiary innovation While patent counts measure the scale of subsidiary innovation, another important factor is the quality of the innovation. The number of citations a patent receives is a good proxy for its quality. Trajtenberg (1990) suggests that patent citations demonstrate the importance of an innovation. Similarly, Gittelman and Kogut (2003) assert that empirical research concludes that highly cited patents represent important technological innovations, owing to the correlation between citations and economic value. To construct this measure, we first considered all semiconductor patents filed by a subsidiary in year *t*. We then computed the total number of citations received by these patents within 6 years[8] of year *t*, termed citing patents. We did not include self-citations by the subsidiary: our measure therefore provided an assessment of quality external to, and independent of, the subsidiary. Citing patents occur subsequent to the subsidiary patent portfolio and reflect the impact and quality of innovation. We then calculated quality by dividing the citations received by the patent portfolio by the scale of the patent portfolio. This gives us a measure of quality in terms of average citations received on a per-patent basis for the subsidiary's patent portfolio.[9]

Independent variables

Knowledge assimilation We measured knowledge assimilation by identifying the existing knowledge utilized by the subsidiary in order to create new knowledge. Since we expected a lag between knowledge assimilation and innovation we considered the subsidiary's patent portfolio in year $t-1$ (i.e., 1 year prior to our dependent variable). We then examined the patents cited by this lagged portfolio. Cited patents were created prior to year $t-1$ (in contrast to the citing patents used to measure quality that are filed after year *t*). They identify the technological antecedents of the innovation, and reflect the knowledge assimilated to create innovation.

Knowledge assimilated from MNC headquarters For each patent in the subsidiary's portfolio in year $t-1$, we identified those cited patents (a) that were assigned to the same MNC,[10] and (b) whose inventor location was in the country of the MNC headquarters.[11] We then divided the count of these cited patents by the total patents filed by the subsidiary in year $t-1$. Thus knowledge assimilated from MNC headquarters is captured as the average number of citations per patent made by a subsidiary's patent portfolio to the headquarters.

Knowledge assimilated from other MNC subsidiaries To determine knowledge assimilated from other MNC subsidiaries we identified, for each patent in the subsidiary's portfolio in year $t-1$, those cited patents (a) that were assigned to the same MNC, and (b) whose inventor location was in a country other than the US and the host country of the subsidiary.[12] We then computed an average number of citations per patent made by a subsidiary's patent portfolio to other subsidiaries in the MNC.

Knowledge assimilated from host country firms We calculated knowledge assimilated from host country firms by identifying those cited patents (cited by subsidiary's patent portfolio in year $t-1$) that (a) were assigned to a firm other than the subsidiary's MNC, and (b) had inventor location in the same country as that of the subsidiary. Knowledge assimilated from host country firms was calculated as the average number of citations per patent made by a subsidiary's patent portfolio to host country firms.

Subsidiary sourcing capability It is difficult to directly observe and therefore measure capabilities. For both sourcing and combinative capability we relied on the measurement of the outcomes of these capabilities as represented by patent data. Sourcing capability of the subsidiary is a function of the subsidiary's knowledge base. We used Henderson and Cockburn's (1996) proxy for knowledge capital to represent subsidiary sourcing capability.[13] We adopted the measure at the subsidiary level, and used the capital stock of patents produced by the subsidiary up to year $t-1$, using a perpetual inventory method with a 20% depreciation rate to reflect sourcing capability.

Subsidiary combinative capability Subsidiary combinative capability was assessed as the extent of integration of knowledge from different sources by the subsidiary. It is a consequence of subsidiary experience in prior recombination of knowledge. To measure combinative capability we developed an indicator (a variation of the Herfindahl index) that captures the breadth of knowledge (in terms of its sources) that the subsidiary has used in past innovation. To do this, we first considered the subsidiary's patent portfolio in the 5 years prior to year *t*. We then determined the proportion of patents cited by this portfolio of patents in six (mutually exclusive and exhaustive) categories: the subsidiary itself; MNC headquarters; other subsidiaries in the MNC; other firms in the host country; other firms in the home country; and other firms in all other countries. We then use the following formula:

$$CC = 1 - \sum_j p_j^2$$

where CC is the combinative capability, and p_j reflects the proportion of citations made by the subsidiary to each category *j* over the last 5 years. CC varies from 0 (when all knowledge has been absorbed from just one source) to 0.83 (where knowledge has been uniformly sourced from the six categories). Thus high values of CC indicate greater experience in combining knowledge from different sources and therefore a higher combinative capability.

Controls

Standardization To control for the general increase in patenting activity in the semiconductor industry over the years, we adjusted the scale and knowledge measures by dividing them by a factor representing the overall 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 year *t* is calculated by dividing the total number of semiconductor patents filed in year *t* by the total number of semiconductor patents filed in 1981. We also checked for differences in the propensity to cite and be cited over time in the semiconductor industry between 1981 and 1992. We found no increase in citing patents. However, there was a significant increase in cited patents. Cited patents increase by a factor equal to the levels of patenting (for which we have adjusted).

Since innovative performance is history or path dependent (Cohen & Levinthal, 1990), we incorporated three separate controls related to prior innovative performance.

Knowledge assimilated from other sources Since our hypotheses focus on only three of the six possible sources of knowledge for MNC subsidiaries, we incorporate knowledge assimilated from the other three sources as control variables. We included knowledge assimilated from the subsidiary itself, knowledge assimilated from other firms in the home country, and knowledge assimilated from other firms in other countries by following the same procedure explained for our independent variables. Each of these is calculated as average number of citations per patent made by a subsidiary's patent portfolio at time $t-1$ to itself, other firms in the home country, and other firms in other countries, respectively.

Lagged dependent variables To overcome possible problems of heteroscedasticity and first-order autocorrelation, we used a lagged *scale of subsidiary innovation* variable, measured as scale of subsidiary portfolio at time $t-1$. This variable was correlated with our subsidiary sourcing capability variable (since sourcing capability includes the scale of prior year's patents) at 0.73. Consequently we do not include it in our runs with scale of subsidiary innovation as the dependent variable. In our analysis of quality of subsidiary innovation, we include *lagged quality of subsidiary innovation* as a control.

Cultural distance Prior research suggests that there are institutional differences in research environments in different countries (Spencer, 2001). These differences are likely to have an impact on the nature of the innovation produced by a subsidiary. Ambos and Chini (2005) demonstrate that coordination between MNC headquarters and subsidiaries is moderated by cultural distance. We similarly expect cultural distance to influence the innovative output of the subsidiary, and control for the possible impact of cultural distance between the host country (where the subsidiary is located) and the home country (US) on subsidiary innovation. We used measures computed by Kogut and Singh (1988) (based on Hofstede's, 1984, cultural dimensions), to test for the impact of cultural distance on innovation.

Firm size There is no consensus on the expected impact of firm size on innovation. Arguments justifying a positive impact propose that size leads to availability of internal funds for innovation, scale economies in R&D, and scope economies owing to complementarities between innovation and other activities (marketing and finance). Counter-arguments propose loss of managerial control and attenuation of incentives of individual scientists in larger firms, leading to inefficiency and less innovation. Firm size was operationalized as the natural log of firm assets in year $t-1$.

Firm R&D intensity Subsidiaries belonging to firms with high R&D intensity are expected to be better able to innovate. R&D expenditures represent the inputs to the innovative process, and prior research has demonstrated that R&D expenditures are significantly correlated with patent output (Hall, Griliches, & Hausman, 1986; Mueller, 1966).[14] Firm R&D intensity was calculated as the firm R&D expenditure divided by firm sales in year $t-1$.

Methods
Studies involving patents and their citations pose a number of econometric and measurement issues, that stem primarily from the count nature of the dependent variable (Hausman, Hall, & Griliches, 1984). A Poisson model is typically suggested for dealing with such dependent variables. However, in a situation of unobserved heterogeneity in the sample that leads to a case termed "overdispersion", the use of a Poisson model causes underestimation of standard errors and an inflation of significance levels. We conducted a goodness-of-fit test for both our comprehensive models. The results for scale of subsidiary innovation indicated a goodness of fit chi-square of 350.75 with a p-value of 0.0000; the findings for quality of innovation had a goodness of fit chi-square of 1653.11 with a p-value of 0.0000. A high and significant value of chi-square (as our tests demonstrated) is an indicator of the presence of overdispersion, and suggests that the Poisson specification is not appropriate. Negative binomial regression models correct for the presence of overdispersion. We followed the approach suggested by Hausman et al. (1984) in their analysis of patent data and followed by other researchers when dealing with event count data (Almeida & Phene, 2004; Kogut & Chang, 1991) by using negative binomial regressions.

We have panel data involving repeated observations of our set of subsidiaries over time, so there may be certain unaccounted subsidiary effects and year effects that are fixed or vary randomly. Fixed effects and random effects models allow us to control for these effects. We performed the Hausman specification test, which determines whether a fixed effects model or a random effects model was appropriate. Our results suggested that in both models, scale of subsidiary innovation (chi-squared statistic 37.53, p-value 0.0001) and quality of subsidiary innovation (chi-squared statistic 39.18, p-value 0.0001), a random effects specification was appropriate. We therefore used a negative binomial regression with random effects for all our models.

FINDINGS
The summary statistics are provided in the Appendix. The sample means suggest that foreign subsidiaries are limited in their ability to generate innovations, producing on average just 0.84 patents per year. These innovations receive 2.08 citations per patent, suggesting that they are not extremely important patents. The most innovative subsidiaries in our sample include Texas Instruments' subsidiaries in Japan and Great Britain, and Intel's subsidiary in Israel. Surprisingly, the knowledge assimilation patterns suggest that these subsidiaries absorb significant knowledge from home country firms and from firms in other countries, with lower amounts of knowledge assimilated from our variables of interest: the MNC headquarters, other subsidiaries in the MNC, and host country firms. An evaluation of the capabilities indicates that subsidiaries typically rely on combining knowledge from only two sources out of the six possible sources of knowledge, with a heavy reliance on home country firms.

We present our findings for subsidiary scale of innovation in Table 1. Model 1 is the baseline model and Models 2 and 3 incorporate the effects of knowledge assimilation and subsidiary capabilities, respectively. Model 4 presents the comprehensive models with all the variables. The Wald statistic suggests that the addition of our independent variables contributes to increased explanatory power (it increases from 20.36 in Model 1 to 50.71 in Model 4).

Knowledge assimilation from the MNC headquarters or MNC subsidiaries is not significant. Hypotheses 1a and 2a are not supported: knowledge assimilated from within firm boundaries does not enhance subsidiary innovation. The lack of a headquarters effect may be a consequence of the

Table 1 Scale of subsidiary innovation: negative binomial regression with random effects

		Baseline model Model 1	*Knowledge assimilation* Model 2	*Subsidiary capabilities* Model 3	*Full model* Model 4
Independent variables					
Knowledge assimilated from					
MNC: HQ	H1a		−0.31		−0.37
			(0.32)		(0.29)
MNC: Other subsidiaries	H2a		−0.03		−0.53
			(1.39)		(1.54)
Host country firms	H3a		0.86***		0.75**
			(0.25)		(0.25)
Subsidiary capabilities					
Sourcing capability	H4a			0.03**	0.02*
				(0.01)	(0.009)
Combinative capability	H5a			1.96**	2.03**
				(0.68)	(0.70)
Controls					
Knowledge assimilated from					
Subsidiary		0.58	0.73	0.33	0.62
		(0.64)	(0.63)	(0.65)	(0.64)
Home country firms		0.21***	0.21***	0.18**	0.20**
		(0.07)	(0.07)	(0.07)	(0.07)
Other country firms		−0.08	−0.06	−0.21	−0.23
		(0.16)	(0.16)	(0.17)	(0.17)
Subsidiary cultural distance		0.05	−0.04	−0.16	−0.15
		(0.23)	(0.23)	(0.20)	(0.20)
Firm size		0.24	0.21	0.003	0.04
		(0.26)	(0.23)	(0.20)	(0.20)
Firm R&D intensity		0.10†	0.10†	0.11†	0.11†
		(0.06)	(0.06)	(0.06)	(0.06)
Wald statistic		20.36**	31.90***	42.24***	50.71***

$N=240$; standard errors in parentheses.
†$p<0.01$, *$p<0.05$ **$p<0.01$ ***$p<0.001$.
Dependent variable: scale of subsidiary innovation.

physical distance between the subsidiary and headquarters, making effective assimilation difficult. The lack of support for Hypothesis 2a may be a consequence of the extremely limited extent of knowledge assimilated from other subsidiaries in the MNC. The mean for this variable is 0.009, indicating that, on a per-patent basis, the average number of times the subsidiary cited other subsidiaries within the MNC is almost negligible. In comparison, the means for knowledge assimilation indicate that external knowledge assimilation is highest from home country firms at 0.78. Hypothesis 3a is supported in both Models 2 and 4. Knowledge from host country firms has a positive and significant impact on scale of innovation. Paradoxically, knowledge assimilated from host country firms is relatively low (mean 0.07), but yet has a significant on innovation. This is in contrast to the effect of knowledge assimilated from other subsidiaries within the MNC. Perhaps it is the physical proximity of the subsidiary to the host country firms that enables effective assimilation from host country firms, leading to a positive impact on scale of innovation. Geographic proximity appears to be more important than organizational context or identity, permitting more effective knowledge assimilation for innovation. Model 2 includes the effects of capabilities on innovation. Sourcing capability has a significant impact on subsidiary scale of innovation: Hypothesis 4a receives support. Combinative capability also has a significant effect on innovation, supporting Hypothesis 5a. Thus both capabilities are critical to scale of innovation.

Of the controls, we find robust effects for the significance of home country firms on scale of innovation. Interestingly, in this case distance does not seem to impede transfer despite the fact that these firms are outside MNC organizational boundaries. We find weak significance for the positive effects of firm R&D on scale of subsidiary innovation.

Our findings for quality of subsidiary innovation are presented in Table 2. The results for quality of innovation are presented in a manner similar to that of scale of innovation, with the baseline model (Model 5), introduction of knowledge assimilation variables (Model 6) and subsidiary capabilities (Model 7), and finally the comprehensive model (Model 8). While the addition of the variables increases the explanatory power of the models, much of the variance seems to be explained by the addition of subsidiary capabilities. A look at the Wald statistic confirms this: in Model 7 it is 51.23, while in Model 8 it is marginally lower at 51.02.

Knowledge assimilated from within the MNC (either from HQ or from other subsidiaries) does not significantly influence the quality of subsidiary innovation. These results are similar to our findings for scale of innovation. Hypothesis 1b and 2b are not supported. The explanations offered earlier for regarding the challenges of accessing knowledge across physical distance appear to apply here as well. Hypothesis 3b is supported: knowledge assimilated from the home country has a significant impact on the quality of innovation. The

Table 2 Quality of subsidiary innovation: negative binomial regression with random effects

		Baseline model *Model 5*	*Knowledge assimilation* *Model 6*	*Subsidiary capabilities* *Model 7*	*Full model* *Model 8*
Independent variables					
Knowledge assimilated from					
MNC: HQ	H1b		−0.09		−0.18
			(0.35)		(0.33)
MNC: Other subsidiaries	H2b		−0.02		0.05
			(1.53)		(1.60)
Host country firms	H3b		1.03***		0.75*
			(0.26)		(0.34)
Subsidiary capabilities					
Sourcing capability	H4b			0.04***	0.03**
				(0.01)	(0.01)
Combinative capability	H5b			1.89**	1.88**
				(0.70)	(0.72)
Controls					
Knowledge assimilated from					
Subsidiary		0.30	0.51	−0.29	−0.07
		(0.70)	(0.74)	(0.75)	(0.78)
Home country firms		0.15*	0.12	0.12	0.11
		(0.07)	(0.08)	(0.08)	(0.08)
Other country firms		0.06	0.04	−0.15	−0.16
		(0.14)	(0.16)	(0.17)	(0.18)
Lagged quality of subsidiary innovation		0.02†	0.01	0.01	0.02
		(0.01)	(0.01)	(0.01)	(0.02)
Subsidiary cultural distance		0.02	−0.05	−0.17	−0.16
		(0.13)	(0.14)	(0.14)	(0.15)
Firm size		−0.19	−0.13	−0.22	−0.19
		(0.14)	(0.15)	(0.17)	(0.17)
Firm R&D intensity		0.02	0.04	0.04	0.05
		(0.05)	(0.05)	(0.05)	(0.06)
Wald statistic		28.46***	49.85***	51.23***	51.02***

N = 240; standard errors in parentheses.
†p < 0.01, *p < 0.05 **p < 0.01 ***p < 0.001.
Dependent variable: quality of subsidiary innovation.

effect of subsidiary capabilities is also significant: sourcing capability (Hypothesis 4b) and combinative capability (Hypothesis 5b) both have a significant impact on the quality of subsidiary innovation. The controls do not demonstrate a significant pattern of effects: knowledge assimilated from home country firms and lagged quality of innovation are significant in the baseline model, but lose their significance in the other models.

Sensitivity Analyses and Robustness Checks

Owing to the high correlation between some of our variables, we employed several sensitivity analyses to ensure the robustness of our findings. The correlation between knowledge assimilated from MNC headquarters and MNC subsidiaries is 0.56, and perhaps this is the reason for a lack of significance for either variable. We ran our full model regressions for scale (i.e., Model 4) and quality (Model 8) without the MNC headquarters variable: our results did not change, and knowledge assimilated from MNC subsidiaries was not significant. We tried alternative runs with the full model, but this time retaining the MNC headquarters variable. Our results were the same, and MNC headquarters did not have a significant effect on the scale or quality of innovation. There were additional correlations within the control variables. Knowledge assimilated from home country firms was correlated with that assimilated from other firms in other countries (0.62) as well as the lagged quality of innovation. We dropped the knowledge assimilated from home country firms from our full runs; however, the knowledge assimilated from other firms in other countries and the lagged quality of innovation did not achieve significance, and our other results stayed the same. When we tried the alternative of dropping knowledge assimilated from other firms in other countries, our results did not change either. Finally firm R&D intensity was correlated with firm size at –0.79. When we dropped firm size from our runs, firm R&D intensity became positive and significant for both scale and quality of innovation, but other results did not change. Alternatively, when we dropped firm R&D intensity, size was not significant in the effects on scale of innovation; however, size had a significant and negative effect on the quality of innovation. The negative effect on quality of innovation supports arguments for loss of managerial control and attenuation of incentives of individual scientists in larger firms.

DISCUSSION AND CONCLUSIONS

One of the primary contributions of our study is that it offers us a clearer picture of the globalization of innovation by highlighting the role that MNC subsidiaries play, and exploring the influences on their innovative ability. Our results suggest that knowledge assimilation from select sources and subsidiary capabilities are critical to the scale and quality of innovation. Our study provides interesting results regarding the question of which sources of external knowledge are useful to subsidiary innovation, differentiating between knowledge from the host country and that from the MNC. Host country knowledge is critical to scale and quality of innovation, while the knowledge absorbed from other subsidiaries and the headquarters within the MNC does not lead to increased innovation.

A non-intuitive result of this study is the limited role of the MNC in subsidiary innovation. An explanation for this may lie in the differentiated nature of the modern MNC. The sub-units of the MNCs play differentiated roles that optimize the capabilities and efficiencies of the MNC as a whole (Bartlett & Ghoshal, 1989). This may require that subsidiaries assume unique technological roles that do not require integration 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 are usually not carried out elsewhere in the firm. Thus these subsidiaries may play an important organizational and strategic role in the MNC but have few technological linkages with the rest of the firm. This could explain the limited knowledge assimilation from other subsidiaries, as this knowledge may not be directly relevant to the subsidiary's own technological agenda. Another factor that could hinder knowledge transfer may be the lack of absorptive capacity on the part of the recipient subsidiary. Thus a subsidiary may not be able to utilize knowledge from within the firm because of its distinctive nature.

A significant and consistent finding emerging from our research is that knowledge assimilated from host country firms is very important to scale and quality of innovation. The findings on the importance of the host country knowledge for innovation support earlier empirical studies as well as theoretical work on ''learning oriented FDI'' (Cantwell, 1989; Dunning, 1994). The examination of our data reveals that the patterns of host country knowledge sourcing vary by country. The knowledge absorption patterns are particularly strong in regions that demonstrate significant knowledge creation, such as those in Haifa, Israel, where every subsidiary sourced knowledge from regional firms. In contrast, subsidiaries in Canada, reflecting the relative lack of regional innovation, learned little from other regional firms. This pattern suggests that subsidiaries tend to assimilate knowledge from those regions that create more knowledge, and this in turn contributes to increased scale and quality of innovation. This finding leads to two important implications: first, not all clusters contribute equally to subsidiary innovation; and second, subsidiaries can strategically choose to locate in clusters depending on the type of knowledge access offered. An interesting extension suggested by this explanation is that different clusters may support different types of innovation. Cohen and Klepper (1996) provide one such characterization of innovation, and suggest that product and process innovation are significantly different. Future research may examine characteristics of specific geographic clusters and their role in fostering either process or product innovation.

Our research suggests that home country firms can also positively affect the scale of subsidiary innovation. Chandler (1990) suggested that MNCs carry with them the influences of their home country when going abroad, and "imprint" these influences on the operations of the subsidiaries. These MNC parent influences include organization practices, systems and modes of structuring, and also perhaps linkages with firms in the home country, leading to knowledge assimilation. These influences may enable easy assimilation, as demonstrated by the significant extent of knowledge sourced from home country firms: more than 50% of total citations were made to home country firms (the average on a per patent basis was 0.78). However, there is no significant effect on quality of innovation. An explanation for our findings is that quality of innovation may be a function of novel knowledge, and linkages to the home country firms may provide redundant knowledge. This knowledge may already be available to the subsidiary from the MNC headquarters, and may not enhance the quality of innovation.

Another contribution of our paper is in highlighting the role of subsidiary capabilities in innovation. Sourcing capability and combinative capability are critical to scale and quality of innovation. The paper supports the idea that the sourcing capability of a subsidiary is related to its prior knowledge stock, and permits the recognition and absorption of knowledge. There is an additional, broader managerial capability, which enables the organization to integrate knowledge. Since Cohen and Levinthal (1989) first introduced the idea of absorptive capacity, the concept has played an important role in research in strategic and international management. Though the authors in their seminal work focused on both absorption and application (or exploitation) of external knowledge, subsequent research has primarily emphasized the sourcing aspect. Lane et al. (2006), in their comprehensive review of the absorptive capacity literature, point to three major shortcomings of this literature: limited attempts to revise the definition of absorptive capacity; little attention to the actual processes underlying absorptive capacity; and few attempts to measure it outside the R&D context. We believe our study addresses two of these issues. By unpacking the concept we focus on the outcomes of the distinct processes of sourcing and recombination. Further, our empirics demonstrate that the concepts of sourcing and combinative capability can be specified through an examination of the firm's knowledge base. While this is still within the R&D context, it is an alternative specification to the typically used R&D intensity measure. Our results demonstrate that, after controlling for firm R&D intensity, sourcing and combinative capability still have an important effect on innovative ability. Our findings indicate that all subsidiaries are not equal; they vary significantly in terms of their innovation capability. Subsidiaries appear to have different mandates: some may be merely low-cost production platforms, while others may be centers of excellence.

Limitations and Extensions

Though this paper highlights some interesting findings regarding the influences on innovation in MNC subsidiaries, the study has several limitations. These limitations suggest caution in the interpretation of our results, and also provide us with opportunities for further research. First, our sample is limited to US-based semiconductor firms. We plan to further study MNCs originating from other countries, as well as those belonging to other high-technology industries. Further, the choice of firms included in our sample was driven by data availability. Thus our sample is not representative of the population but rather a convenience sample, and our findings may not translate to the population of semiconductor firms.

Second, we use only patents as indicators of innovative performance. This narrows our focus to technological innovations, articulated knowledge, and the associated capabilities. We recognize that other types of innovation are important to firm success, and exist across different stages of the value chain.[15] In future studies we propose to employ a survey instrument to incorporate indicators of broader innovation and capabilities.

Third, given data limitations, we could not distinguish between types of subsidiary. Overseas subsidiaries may be either greenfield subsidiaries or acquisitions. Acquired subsidiaries are more likely to be embedded in the local context, and therefore will demonstrate greater knowledge assimilation from host country firms. We did not have access to data to classify our subsidiaries as greenfield or acquisitions, and are therefore unable to control for its effect on knowledge assimilation.

Fourth, our study provides only a picture of the patterns of knowledge assimilation by subsidiaries; it does not identify specific mechanisms of knowledge assimilation or the nature of the knowledge itself. We infer knowledge assimilation based on patent citations; however, this measure is subject to noise, and knowledge assimilation is not completely captured by our variable. We draw some assumptions regarding the nature of knowledge assimilated from the MNC headquarters and other subsidiaries (technologically differentiated) and from the home country (redundant knowledge) and the associated mechanisms, such as proximity and social networks in host country regions and organizational structure and routines within the MNC. In future studies we hope to identify the actual mechanisms of knowledge assimilation and the nature of knowledge assimilated to determine their role in innovation.

Finally, our conclusions regarding sourcing and combinative capabilities are subject to the same limitation faced by much of the prior empirical research on absorptive capacity. We cannot directly observe these capabilities but only infer and make attributions about firm internal routines relating to sourcing and combinative capability.[16] Future research can focus on examining these routines directly to determine whether the attributions made are supported.

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NOTES

[1]MNC subsidiaries can assimilate knowledge from a set of six exhaustive and mutually exclusive sources: the subsidiary itself (i.e., utilizing own knowledge), MNC headquarters, other MNC subsidiaries, other firms in the host country, other firms in the home country, and other firms in other countries. Our theoretical arguments focus on a few of these sources since they have been deemed to be important; however, we control for the effects of all six sources.

[2]We use the term ''host country'' to reflect the country where the subsidiary is located; ''home country'' refers to the country where MNC headquarters are located. This is in line with convention in the subsidiary literature (Almeida & Phene, 2004; Frost, 2001; Kuemmerle, 1999).

[3]While we focus on knowledge assimilated from these three sources, our empirical analysis includes all six sources.

[4]Although it is the subsidiaries that demonstrate differentiation and diversity, the HQ is also expected to play a role in channeling knowledge to the appropriate subsidiary in the absence of lateral linkages between the subsidiaries.

[5]We thank the editor for this suggestion.

[6]The six semiconductor firms represented in our sample are AT&T, Intel, Motorola, National Semiconductor, Rockwell Semiconductor and Texas Instruments.

[7]The US 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 three-digit level. Our discussion with patent examiners indicated that 20 broad technology classes, encompassing hundreds of nine-digit technology classes, covered the entire spectrum of semiconductor knowledge and contributed to 95% of the innovatory activity in the semiconductor industry. Thus scale of subsidiary innovation measures the number of patents filed by the subsidiary in these 20 classes in a particular year.

[8]Typically, five years is the duration of a product life cycle in the semiconductor industry (Stuart & Podolny,

1996), and therefore allowing for a 6-year period for citations should provide an accurate reflection of the importance of the patent.

[9]We used the integer value of this variable (e.g., if this variable had a value of 7.71, it was rounded up to 8) in order to use the negative binomial regression and facilitate comparisons with the model for scale of innovation. We also computed an alternative measure of quality as a pure count of total cites (rather than the average), and ran our regressions with the alternative measure. Our findings were robust across both measures.

[10]We compared assignee names on the subsidiary patent and the cited patent to ensure that they belonged to the same firm.

[11]The country of MNC headquarters in our sample was the US, since our sample consists only of US semiconductor firms.

[12]This eliminates citations to MNC headquarters that are considered separately and self-citations by the subsidiary that are discussed in the controls.

[13]We are grateful to an anonymous reviewer for suggesting this approach.

[14]We would have preferred to use subsidiary-level R&D intensity and contacted the firms in our sample for information on subsidiary R&D expenditure and sales. However, they were unwilling to disclose this information.

[15]Thanks to a reviewer for pointing this out.

[16]We thank the editor for this suggestion.

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APPENDIX

See Table A.

Table A Means, standard deviations and correlations

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
Dependent variables														
Subsidiary innovation														
1. Scale of innovation	1.00													
2. Quality of innovation	0.33	1.00												
Independent variables														
Knowledge assimilated from														
3. MNC HQ	0.12	0.002	1.00											
4. Other subsidiaries in MNC	0.02	−0.01	0.56	1.00										
5. Host country firms	0.57	0.13	0.23	0.04	1.00									
Subsidiary capabilities														
6. Sourcing capability	0.67	0.14	0.14	0.03	0.61	1.00								
7. Combinative capability	0.34	0.16	0.33	0.13	0.29	0.36	1.00							
Controls														
Knowledge assimilated from														
8. Subsidiary	0.23	0.01	0.10	0.07	0.02	0.12	0.21	1.00						
9. Home country firms	0.30	0.10	0.35	0.31	0.21	0.26	0.28	0.22	1.00					
10. Other firms in other countries	0.29	0.08	0.33	0.33	0.10	0.20	0.41	0.33	0.62	1.00				
11. Lagged quality of innovation	0.15	0.08	0.13	−0.01	0.14	0.14	0.20	0.13	0.49	0.37	1.00			
12. Cultural distance	0.08	−0.08	−0.0001	−0.09	0.17	0.16	−0.01	−0.13	−0.06	−0.11	−0.07	1.00		
13. Firm size	−0.14	−0.05	0.11	0.05	−0.13	0.06	0.007	−0.09	−0.09	−0.07	−0.02	−0.13	1.00	
14. Firm R&D intensity	0.10	0.04	−0.10	−0.06	0.05	0.06	−0.02	0.09	0.10	0.07	0.03	0.11	−0.79	1.00
Mean	0.84	2.08	0.14	0.009	0.07	3.23	0.27	0.02	0.78	0.33	2.25	1.28	8.97	7.73
Standard deviation	2.36	6.48	0.52	0.10	0.32	6.82	0.26	0.13	1.75	0.83	6.58	1.10	1.50	4.02

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