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KNOWLEDGE SPILLOVERS AND THE ASSIGNMENT OF R&D RESPONSIBILITIES TO FOREIGN SUBSIDIARIES

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Research on R&D location choice by MNCs has focused largely on host country factor endowments and overlooked the role that the potential to capture and utilize knowledge spillovers from competitors may also play in determining such choices. Using a large-scale panel database of the foreign subsidiaries of U.S.-based MNCs in above-average R&D-intensive industries, we examine the extent to which external spillover opportunities as well as internal firm-specific capabilities to utilize such knowledge affect MNCs' new R&D location decisions. Our findings suggest that MNCs appear to anticipate potential spillover opportunities and are discriminating in assessing these opportunities not only across locations but also across categories of competitors within the same location. Further, our findings provide stronger support to predictions regarding the salience of global utilization capacity than they do to predictions regarding the salience of local utilization capacity. Copyright © 2004 John Wiley & Sons, Ltd.

Some of the most important decisions by MNCs involve the location of specific activities in the value chain (Buckley and Casson, 1976; Caves, 1971; Dunning, 1980; Hymer, 1976; Kogut 1985; Porter, 1986). Over the last few decades, the bulk of research on this topic has focused on location choices pertaining to foreign direct investment (FDI) in *manufacturing* operations (e.g., Coughlin, Terza, and Arromdee, 1991; Feinberg and Keane, 2001; Head, Ries, and Swenson, 1995; Hennart and Park, 1993; Kogut and Chang, 1991; Shaver and Flyer, 2000). In contrast, relatively less research has focused on the factors that drive MNCs' choices regarding the location of *research and development* (R&D) activities (Cheng and Bolon, 1993; Penner-Hahn, 1998).

A possible explanation for the limited, albeit growing, focus on R&D location choice is that, relative to the globalization of production, the globalization of R&D is a more recent phenomenon. Research on FDI has historically started from the premise that, for the typical MNC, R&D is likely to be concentrated in the home country. Thus, the global exploitation of technology assets is best achieved through an 'internalized' transfer of technology from headquarters to foreign production units owned and controlled by the firm (Buckley and Casson, 1976; Caves, 1971, 1982; Hymer, 1976; Rugman, 1981; Vernon, 1966). Recent research indicates, however, that firms are rapidly increasing their commitment to foreign R&D activities. According to a survey by the U.S. Department of Commerce (Dalton, Serapio, and Yoshida, 1999), foreign R&D spending by U.S.-based MNCs nearly tripled from $5.2 billion in 1986 to $14.1 billion in 1997 and accounted for 11 percent of total R&D spending of U.S.-based MNCs by the latter date. Similar observations hold

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true for non-U.S. MNCs as well. R&D spending by foreign-owned companies in the United States tripled from $6.5 billion in 1987 to $19.7 billion in 1997, and accounted for nearly 15 percent of total corporate R&D spending in the United States.

Furman, Porter, and Stern (2002), Lee and Procter (1991), and others have also argued that empirical evidence suggests a growing technological parity among most of the developed and some of the developing countries. Thus, assigning R&D responsibilities to foreign units is becoming significant not just as an enabler of technology transfer from the home to the host country but also as a source of new knowledge for the entire corporation. As the authors of the Department of Commerce report observed, 'Learning has emerged as a key element in the globalization of R&D. More and more companies are viewing direct investment in R&D as not only a vehicle for transferring a parent company's technology to the host country but, more important, as an opportunity to learn and develop externally-developed science and technology' (Serapio, Dalton, and Yoshida, 2000: 3).

This study contributes to the emerging literature on the globalization of R&D by examining *how the potential to capture spillovers of external knowledge and the MNCs' internal capacity to utilize such knowledge influence MNCs' decisions to assign R&D responsibilities to existing foreign subsidiaries.* Because such decisions imply a significant change in the charters of the affected subsidiaries and are costly to reverse, they constitute some of the most salient strategic decisions for MNCs. Focusing on both *external* and *internal* factors, our aim is to predict and explain variations in subsidiary-level R&D assignments not only across subsidiaries within the same MNC but also across MNCs.

In explaining why an MNC would choose a particular subsidiary as a preferred location for R&D activities, extant research has focused almost exclusively on local factor endowments such as the level of the host country's technological sophistication (Kumar, 1996; Kummerle, 1999; Pearce and Singh, 1992; Zejan, 1990). With rare exceptions (e.g., Florida, 1997; Fors, 1998), the literature has almost entirely ignored the salience of potential knowledge spillovers in driving MNCs' R&D location decisions. As we discuss below, this oversight has resulted in a significant gap in theory development regarding the globalization of R&D.

Spillovers should be important to the R&D location decision because research on the geography of organizational knowledge has consistently revealed that spillovers of technical knowledge tend to be localized, and that such spillovers have a significant positive impact on the returns that firms get from investment in their own R&D efforts (Almeida and Kogut, 1999; Audretsch and Feldman, 1996; Jaffe, Trajtenberg, and Henderson, 1993). These findings are interesting because, given the intangible nature of technical knowledge, one might expect that its mobility would be far less constrained by geography than the transfer of tangible goods such as components or finished products. Yet, as Almeida and Kogut (1999) and Jaffe *et al*. (1993) have argued, technology spillovers tend to be localized principally because technology transfers often involve the transmission of not just codified but also tacit knowledge (Polanyi, 1966).

As is well established by now, the effective and efficient transmission of knowledge requires that there be an alignment between the structure of knowledge and the capacity of transmission channels (Daft and Lengel, 1986). Accordingly, tacit knowledge is most appropriately transferred through either direct face-to-face interaction or the mobility of knowledge-carrying individuals across organizations (Gupta and Govindarajan, 2000; Hansen, 2002; Zander and Kogut, 1995). Geographic proximity facilitates face-to-face interaction in both official as well as social contexts. It also increases the likelihood of employee mobility across firms. The importance of geographic proximity to the transfer of tacit knowledge thus emerges as the primary explanation behind the localization of technology spillovers.

It is also noteworthy that, in recent years, knowledge spillovers have emerged as a critical factor in explaining location choice for foreign *manufacturing investments* (e.g., Chung and Alcacer, 2002; Head *et al*., 1995; Shaver and Flyer, 2000). Since *R&D activities* are more knowledge-driven than manufacturing, we would anticipate that the opportunity to access and utilize knowledge spillovers should be an even greater driver of R&D as compared with manufacturing location choices. Yet, this idea has remained largely unexplored, both theoretically and empirically. Given that 'R&D location choices are particularly important for companies that aspire to global strategies' (Porter and Stern, 2001: 35), major theoretical gaps in our

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understanding of the factors that drive R&D location choice represent a significant research opportunity. The primary goal of this study is to help redress this deficiency.

Our theoretical predictions focus on the assignment of new R&D responsibilities to existing subsidiaries that had no R&D activities in the previous year. Our data source consists of the Benchmark and Annual Surveys of U.S. Direct Investment Abroad administered by the Bureau of Economic Analysis, U.S. Department of Commerce (BEA). We use the BEA data disaggregated at the individual foreign affiliate level for each U.S.-headquartered MNC from 1989 through 1996.

This paper is organized as follows. First, we develop our theoretical arguments and hypotheses. These are followed by data and research methods. We then present our results and conclude with a commentary on our findings as well as directions for future research.

THEORY AND HYPOTHESES

We conceptualize the assignment of new R&D responsibilities to a subsidiary as a strategic investment in the subsidiary's capacity to accumulate technical knowledge through an interplay between the subsidiary's internal creative efforts and the absorption of external knowledge that might spill over from other firms conducting R&D in the host country (Cohen and Levinthal, 1990). As with most strategic decisions, we contend that such decisions are likely to be influenced by a consideration of both external opportunities as well as internal firm-specific capabilities. In other words, the probability that a subsidiary would be assigned R&D responsibilities is likely to be higher when the nature of R&D activities by other firms in the host country offers greater potential for knowledge spillovers, and when the parent MNC has a more developed internal capacity to utilize the subsidiary's newly acquired knowledge both locally and globally.

As developed in greater detail below, with regard to external spillover opportunities, we focus on two characteristics of the host country R&D activities of other firms in the same industry as the focal subsidiary: the total magnitude and the interfirm dispersion of R&D. Focusing on same industry firms is important because knowledge spillovers that are more related to the focal subsidiary's own knowledge base are likely to be more useful than those of less related knowledge (Hansen and Lovas, 2004). With regard to the MNC's internal capacity for utilization of knowledge, we focus on three sets of factors: the MNC's capacity for local utilization at the subsidiary level, the MNC's capacity to appropriate the subsidiary's knowledge for global use, and the MNC's capacity to deploy such knowledge to other parts of the global network. We focus on some properties of specific subsidiaries as well as on some properties of the entire MNC. Even though our aim is to explain variations in the likelihood that specific subsidiaries would be assigned R&D responsibilities, properties of the MNC as a whole become important when there are strong reasons to believe that these properties may affect the likelihood of any subsidiary being assigned R&D responsibility. Other things equal, the likelihood of a subsidiary being assigned R&D will depend critically on the extent to which its parent MNC has put in place structures and routines to transfer and use globally sourced knowledge. We now develop our specific hypotheses, dealing first with external then with internal factors.

External spillover opportunities

Saxeninan (1994) has provided persuasive evidence that managers are highly cognizant of the phenomenon of interfirm knowledge spillovers as well as the fact that a high proportion of spillovers tend to be geographically localized. Accordingly, we would expect that managers are likely to take into account future spillover potential when making decisions regarding where to locate new R&D facilities. It is important to note here that, at the point of deciding where to assign R&D responsibilities, it is impossible for MNC managers to know exactly what the magnitude of future spillovers will be. Instead, what they are likely to focus on are indicators that signal a higher or lower potential for future knowledge spillovers. We propose that the *total magnitude* as well as the *interfirm dispersion* of host country R&D conducted by other firms in the same industry would be two important indicators of a host country's spillover potential. We focus on each of these variables in turn.

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Magnitude of other firms' R&D

Our theoretical arguments regarding the salience of the total magnitude of R&D by other firms are straightforward. Greater R&D expenditure by other firms would, on average, produce a more abundant and diverse supply of technical knowledge which might potentially spill over. Greater R&D expenditure is, on average, also likely to be associated with the employment of a larger number of scientists and engineers, any one or more of whom are potentially mobile across firms. Consistent with these arguments, empirical studies have demonstrated that, the greater the scale of R&D by other firms within the same region and industry, the greater are the returns to focal firms from their own investments in R&D (Bernstein and Nadiri, 1988, 1989; Jaffe, 1986).

An interesting theoretical question pertains to whether, within the population of other same-industry firms conducting R&D within the host country, the focal MNC would perceive differences in spillover potential from the local R&D activities of U.S. MNCs vs. those of non-U.S. firms. Literature on the diffusion of innovations between independent firms (e.g., Rogers, 1995), joint venture partners (e.g., Lane and Lubatkin, 1998), as well as peer subunits within the larger firm (e.g., Gupta and Govindarajan, 2000) has consistently discovered that, *ceteris paribus*, knowledge flows are greater between organizations that are more similar. The theoretical explanation is that similarity fosters communication links, increases the perceived relatedness of knowledge, and, as suggested by institutional theory (DiMaggio and Powell, 1983), increases the pressures for mimetic isomorphism. Thus, it is not unlikely that, in deciding where to locate new R&D facilities, U.S.-based MNCs may respond positively, but with differing degrees of salience, to the magnitude of same-industry R&D being done in the host country by other U.S.-based MNCs vs. non-U.S. firms (see also Feinberg and Majumdar, 2001). Leaving this issue of relative salience to empirical examination, we hypothesize that:

Hypothesis 1: The probability of assigning R&D responsibility to an existing foreign subsidiary will be positively associated with the total R&D expenditure by other same industry firms (both U.S. MNCs as well as non-U.S. firms) within the host country.

Interfirm dispersion of host country R&D

While the magnitude of R&D refers to the total amount of R&D being done by other firms, dispersion refers to the distribution of R&D expenditure across firms. Consider three scenarios where, in each case, the total scale of other firms' R&D is \$100 million. In scenario A, all R&D is done by one firm; in scenario B, this R&D represents expenditures of \$60 million, \$20million, \$15 million, and \$5 million by each of four firms; finally, in scenario C, this R&D is done by four firms, each spending \$25 million each. As can be seen, in these three cases, R&D is most concentrated in scenario A and least concentrated in scenario C. This example also illustrates that interfirm dispersion of R&D depends not just on the number of other firms doing R&D but also on the variance in the amount of R&D being done by the firms.

We propose that, as an indicator of potential spillover opportunities, dispersion of other firms' R&D would matter because, the greater the dispersion, the greater would be the potential spillovers. There are two possible mechanisms through which dispersion of other firms' R&D can be expected to affect potential spillovers. First, for both history dependence as well as strategic reasons, the likelihood is high that, even within the same industry, firms differ from each other in some important respects (Lippman and Rumelt, 1982). Thus, dispersion of R&D across a larger number of firms is likely to result in greater diversity in the technology projects being pursued and, as a result, in the content of the technical knowledge that could spillover. For the focal firm, the relevance of external knowledge depends not just on whether it is related to the firm's own knowledge base (Hansen and Lovas, 2004) but also on whether it is different from what the firm already knows (Galunic and Rodan, 1998). Accordingly, *ceteris paribus*, the greater the dispersion of R&D across firms, the greater would be the potential relevance of externally available technology for the focal firm.

The second mechanism through which interfirm dispersion of other firms' R&D may affect potential spillovers deals with the likelihood of spillovers despite firms' efforts to prevent unintended leakage to others. We take it as given that every competitor would do its best to guard its own intellectual property and minimize outgoing

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spillovers. However, if these efforts at leakage prevention are less than perfect, as they typically will be (Almeida and Kogut, 1999; Jaffe *et al*., 1993), then the higher the dispersion of R&D expenditure across firms, the greater would be the probability that the focal subsidiary will be able to access external spillovers. Thus:

> *Hypothesis 2: The probability of assigning R&D responsibility to an existing foreign subsidiary will be positively associated with the interfirm dispersion of R&D by other same-industry firms within the host country.*

An important question arises regarding the likelihood of interaction (in the form of a possible substitution effect) between the scale and dispersion of total host country R&D by other firms. When the scale of R&D being conducted in the host country by other firms is not very large, the extent to which the R&D is concentrated or dispersed should have greater import. In such cases, the greater diversity of knowledge created by competitors and the potential for more leakages should signal a greater potential for spillovers to the focal subsidiary. However, when the scale of R&D activities in the local market is very large, the potential advantages of dispersion should decline for two reasons. First, when the scale of R&D becomes very large, we would expect the number and scope of R&D projects to become more diverse even if all of the R&D were to be concentrated in just one firm. Thus, very large scale should reduce somewhat the spillover advantages of R&D diversity resulting from dispersion across firms. Second, greater scale of R&D is also likely to necessitate a larger number of R&D employees who could potentially serve as channels for spillover. This increase in the likelihood of spillovers associated with scale should also reduce the advantage of interfirm R&D dispersion in fostering spillovers. Thus:

> *Hypothesis 3: Controlling for main effects, the probability of assigning R&D responsibility to an existing foreign subsidiary will be negatively associated with the interaction between the total magnitude and the interfirm dispersion of R&D by other same industry firms within the host country.*

Internal capacity for knowledge utilization

The R&D resources of any foreign subsidiary can play one or both of two roles: facilitate local adaptation of the MNC's products and services and/or enable the creation and acquisition of globally relevant technology for the entire corporation. Reflecting the organization and behavior of MNCs until that time, Vernon's (1966) product life cycle theory emphasized the primary role of foreign R&D as being that of facilitating local adaptation. Since then, however, several studies have revealed that, in recent years, many foreign R&D units have begun to play a global knowledge-seeking and knowledge-creation role (Florida, 1997; Frost, 2001; Gupta and Govindarajan, 2000). As an example of a new R&D unit established from the start with a dual local adaptation plus global knowledge-seeking role, Dalton *et al*. (1999: 43) cite the case of IBM's research laboratory in China: 'The laboratory's initial mandate is to conduct specialized research focusing on Chinese language and speech recognition, as well as to conduct digital library technology research. The research outputs from this laboratory are intended to benefit the Chinese market as well as IBM's worldwide operations.'

In this study, we allow for the possibility that the R&D units of foreign subsidiaries can, but need not always, play a dual local and global role. Accordingly, we propose that the likelihood of a given subsidiary being assigned R&D responsibilities would be positively associated with the MNC's capacity for both local and global utilization.

MNC's capacity for local utilization

We focus first on the MNC's capacity for local utilization. We argue that, other things being equal, the greater the local market focus of the subsidiary, the greater would be the subsidiary's investments in sensing and responding to the needs of local customers. A subsidiary can sell all of its output exclusively within the host country, sell all of it through exports outside of the host country, or some combination of the two. The greater the proportion of its revenues that a subsidiary derives from sales within the host country, the more locally focused the subsidiary would be expected to be. As such, local market focus can be regarded as a valid indicator of the subsidiary's capacity for local utilization of its technical knowledge. In this study,

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we operationalize local market focus in terms of the proportion of its revenue that a subsidiary derives from the local market. Hence:

Hypothesis 4: The probability of assigning R&D responsibility to an existing foreign subsidiary will be positively associated with the proportion of the subsidiary's revenues derived from local sales in the host country.

MNC's ability to appropriate the subsidiary's technical knowledge

Building on transaction cost economics (Coase, 1937; Williamson, 1979), we argue that the extent of the MNC's ownership stake in the focal subsidiary is likely to be a key driver of its ability to appropriate the latter's knowledge. In a context of shared ownership, the MNC is likely to be at least partly constrained by the economic stakes of other owners in appropriating the subsidiary's knowledge for its own use. Given the nature of technical knowledge as a specialized intermediate good, there generally are no comparable market prices; thus, agreeing on an appropriate pricing mechanism for transfers of knowledge from the subsidiary to the MNC may be either too time consuming or simply impossible (Arrow, 1974; Caves, 1982). Either way, the lower the MNC's ownership control over the subsidiary, the greater would be the transaction costs it would likely incur in appropriating the subsidiary's technical knowledge for global use (see also Gatignon and Anderson, 1988; Gomes-Cassares, 1989).

Building on the above arguments, we predict both a 'stock' and a 'flow' level connection between ownership stake and the probability of assigning R&D responsibilities to the focal subsidiary. In other words, when assigning R&D responsibilities to a foreign subsidiary, we predict that corporate executives would prefer to have as high an ownership stake as feasible, based not only on historical decisions regarding ownership but also on recent moves to increase the ownership stake further. These static as well as dynamic associations between ownership stake and capacity to extract and absorb knowledge spillovers are reflected also in a recent essay by Cantwell and Narula (2001: 159): 'MNCs with greater initial ownership advantages have a greater absorptive capacity to be able to extract and utilise the potential for new innovation to be found in foreign centres of excellence ... Similarly, in a successful process of international network creation in the MNC, ownership and location advantages are cumulatively developed together.' Thus:

Hypothesis 5: The probability of assigning R&D responsibility to an existing foreign subsidiary will be positively associated with (a) the MNC's ownership stake in the subsidiary, and (b) recent moves to increase the ownership stake further.

MNC's organizational ability to transfer the subsidiary's knowledge

Here, we focus on properties of the entire MNC rather than on those of specific subsidiaries. As indicators of the MNC's ability to transfer subsidiary-level knowledge throughout the MNC, we focus on two properties of the MNC: the extent of cross-border intrafirm trade between the parent and its foreign subsidiaries, and the number of existing subsidiaries with R&D responsibilities within the MNC's global network.

Our focus on cross-border intrafirm trade rests on the belief that such trade cannot occur without the concurrent presence of organizational mechanisms to share information and coordinate the activities of various subsidiaries. Consistent with Kobrin (1991), we argue that the extent of intrafirm trade between the parent and foreign subsidiaries is a highly reliable indicator of the extent to which the MNC is organized and managed in a globally integrated manner, i.e., has established communication and coordination mechanisms to link various subsidiaries and corporate headquarters to each other. Unlike *interfirm* trade, *intrafirm* trade is far more likely to involve intermediate goods such as components and subassemblies (Hymer, 1976; Rugman, 1981). For such trade to occur, the MNC must create formal as well as informal structures and processes to foster communication between people located in different subsidiaries as well as corporate headquarters. These communication links can be expected to create opportunities for people embedded in different subunits of the MNC to discover possibilities to leverage know-how from one part of the firm to another (Galunic and Rodan, 1998). The importance of formal and informal organizational ties is supported also in a recent study by Hansen and Lovas

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(2004), who reported that, within an MNC, existing organizational linkages were even more important than relevance of knowledge in determining who contacted whom to seek knowledge. To sum up, MNCs which engage in greater intrafirm trade can be expected to have a more developed capacity to utilize the knowledge accumulated by any particular subsidiary on a global basis. Thus, we hypothesize that:

> *Hypothesis 6:The probability of assigning R&D responsibility to an existing foreign subsidiary will be positively associated with the magnitude of intrafirm trade between the MNC's U.S. operations and its foreign subsidiaries.*

Our focus on the second indicator, the number of existing R&D units within the MNC's global network, rests on the premise that, up to a point, MNCs with a larger number of preexisting foreign R&D units are more likely to have the absorptive capacity to transfer and utilize any subsidiary's knowledge on a global basis. There are two reasons behind this expectation. First, a firm with more R&D units has more places within the organization that may have the capacity to utilize novel scientific and technological knowledge. These units are likely to have acquired the ability to absorb discoveries from outside through prior R&D experience (see also Tripsas, 1997). Second, an MNC with more foreign R&D units is likely to have had greater opportunity and thus greater experience at building communication linkages among the various subsidiaries in order to leverage the technological knowledge of these units. These intrafirm linkages are likely to serve as an asset in utilizing the knowledge accumulated by any new R&D unit on a global basis. Along similar lines, Cantwell and Narula (2001: 160) argued recently that 'in the more ... internationally integrated or "globalized" MNC, the geographical dispersion of innovation may come to facilitate the technological development of the firm, since the MNC can tap into alternative streams of innovation in different centres, and establish favorable cross-border interactions between them.'

While we have argued above in favor of a linear and positive relationship between the number of foreign R&D units already in place and the likelihood of assigning R&D responsibilities to yet another subsidiary, there are reasons to expect that the relationship between these two variables is likely to be curvilinear (inverted U) rather than linear. There are several reasons behind this expectation. First, beyond a certain point, a larger number of R&D units is more likely to result in duplicative efforts, thereby reducing the need for knowledge transfers. Second, the presence of a large number of R&D units may suggest that the firm is decentralizing and pursuing a multi-domestic rather than global strategy (Porter, 1986). In such a case, the R&D activities of the various subsidiaries may be focused largely towards product development for the host country market, thereby also reducing the need for intrafirm knowledge transfers. Third, increasing geographic dispersion of R&D activities may result in a loss of scale and critical mass at the various individual locations. Once the MNC's geographic dispersion of R&D activities has reached this point, it is likely to experience negative returns from additional geographic dispersion of R&D activities. Hence:

> *Hypothesis 7: The probability of assigning R&D responsibility to an existing foreign subsidiary will have a curvilinear (inverted U-shaped) relationship with the total number of foreign R&D units already in place.*

METHOD

Sample

The dataset used in this research is from the Benchmark and Annual Surveys of U.S. Direct Investment Abroad, administered by the Bureau of Economic Analysis, U.S. Department of Commerce. Containing detailed financial and operational data on the entire population of U.S.-based MNCs and their foreign affiliates, the BEA data are the most comprehensive data available on MNCs.

In this study, we use BEA data disaggregated at the individual foreign affiliate level for each MNC from 1989 through 1996. A foreign affiliate is defined as 'a foreign business enterprise that is directly or indirectly owned or controlled by one U.S. person, to the extent of 10 percent or more of the voting securities for an incorporated business enterprise or an equivalent interest for an unincorporated business enterprise' (See Bureau of Economic Analysis, March 1999, for a thorough description of definitions and survey methodology used by the BEA). Foreign affiliates, as they

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are defined by the BEA, are analogous to foreign business units in the sense that MNCs are typically only permitted to consolidate operations in a particular country into a single 'affiliate' if these operations are in the same three-digit industry or are integral parts of the same business operation.[1] Consequently, affiliates are typically not diversified. The median affiliate in our sample has 100 percent of its sales revenue in one 3-digit industry, and the average affiliate has 93 percent of its sales in one industry.

To test our hypotheses on R&D assignments, we use a subset of the BEA data which we constructed in several steps. First, because the BEA data contain both reported and estimated observations on foreign affiliates, we exclude all estimated data from our sample. This step reduced the potential affiliate–year observations from 154,713 to 70,093.[2] Second, we restrict our sample to majority-owned (>50%) affiliates, because minority-owned affiliates often provide much less comprehensive data to the BEA. Third, we use only affiliates in 11 OECD countries because our data on local firm R&D was only available for 15 OECD countries, and we had insufficient observations to include affiliates from the Nordic countries (Denmark, Finland, Norway, and Sweden). From the standpoint of coverage, the 11 OECD countries included in our final sample account for over 88 percent of all R&D by affiliates that report data. Finally, we limited our sample to R&D-intensive industries (defined here as industries with greater-than-average affiliate R&D/sales). The industries included in our study are: industrial chemicals, pharmaceuticals, scientific equipment, automobiles, transportation, computers, electrical machinery, electronic components, minerals, and non-electrical machinery. These industries are also industries for which we could match BEA and OECD data by 3-digit industry code.[3]

After these four screens, our sample had 9189 affiliate–year observations. Since all affiliate and MNC variables are lagged, observations from the year 1989 were not included in the regression sample. We also eliminated from our sample all affiliates that already had R&D operations in 1989, or in the first year in which they appeared in the sample. We then had to restrict our sample to affiliates with no missing data and at least two consecutive observations to create lagged variables. These final screens, along with the removal of observations on affiliates in years after the assignment of R&D responsibilities, left us with a sample of 2306 affiliate–year observations on 989 affiliates of 361 U.S. MNC parents. Our final sample includes 676 affiliate–year observations on 328 affiliates that were assigned R&D during the sample period and 1630 affiliate–year observations on 661 affiliates that were not assigned R&D during this period.

Dependent variable

Probability of assigning R&D responsibilities to an existing subsidiary

Our dependent variable, PROB-R&D$_{ijct}$, is the probability that a subsidiary which did no R&D in the previous year is assigned R&D responsibilities in the current year. The subscripts denote the following: i indicates the focal subsidiary, j is the industry of the focal subsidiary, c is the focal subsidiary's host country, and t denotes time. Since subsidiary i is our unit of analysis for all variables, we suppress this subscript in the definitions that follow. We use subscripts only as needed, if variable definitions differ in any of the country, industry, or time dimensions. PROB-R&D is a 0–1 variable which equals 1 if a subsidiary that existed but did not do any R&D at time $t-1$ does R&D at time t. As noted above, 328 of the 989 affiliates were assigned R&D responsibilities during the time window 1990–96.[4]

[1] The BEA gives the following example of subsidiaries which are part of 'the same business operation.' 'If Mexican subsidiary A manufactured automobile engines and a majority of its sales were to Mexican subsidiary B, which assembled automobiles, then subsidiaries A and B could have been consolidated' (BEA, March 1999).

[2] The estimated data arise because the BEA conducts two different surveys: the Benchmark *and* Annual Surveys of U.S. Direct Investment Abroad. In the Benchmark Surveys (conducted in 1989 and 1994), the BEA includes the whole population of foreign subsidiaries, and typically lowers the reporting requirements for subsidiaries, in terms of size. These requirements are often raised in the non-Benchmark years, which means that the BEA does not require smaller subsidiaries to fill out the surveys, but carries them forward by estimating data. We remove these estimated observations in the present study. Note that the individual subsidiaries which are carried forward are small and thus not likely to have a significant impact on the BEA's published data at the industry or country level.

[3] These 10 industries account for 70 percent of all R&D by subsidiaries that report data.

[4] Note that it is possible that, because the BEA defines a subsidiary according to its economic activity (as represented by its industry and the definition of a subsidiary above), a

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Predictor variables[5]

Total R&D expenditure by other firms

This measure is similar to R&D spillover variables widely used in empirical work (e.g., Griliches, 1991).[6] We separate the total R&D expenditures by other firms into the R&D expenditures of U.S. MNCs and non-U.S. firms, both in the same host country and industry as the focal subsidiary. We measure *non-U.S. firms' host country R&D* as the lagged sum of all R&D conducted by firms in the host country, other than U.S. MNCs, in the industry of the focal subsidiary. We construct this measure by subtracting from the total R&D expenditures the R&D conducted by subsidiaries of U.S. MNCs. Data on the R&D activities of local firms were obtained from the ANBERD (Analytical Business Enterprise Research and Development) database compiled by the OECD (see OECD, 2002). We use a log transformation of this variable to mitigate heteroscedasticity. We measure *U.S. MNCs' host country R&D* as the lagged sum of all R&D conducted in the same country and industry as the focal subsidiary by other U.S. MNC subsidiaries. This variable was constructed out of the sample by using BEA data on the entire population of U.S. MNC subsidiaries in each country–industry. We use a log transformation of this variable.

Interfirm dispersion of host country R&D

In creating this variable, we use a measure of 'dispersion' inspired by the Herfindahl index used by economists and the government to measure market share 'concentration' within an industry. The Herfindahl is equal to the sum of the squared market shares of all firms, multiplied by 10,000 (Oster, 1990: 213). We use the same underlying computational logic, but we focus on dispersion rather than concentration.

We do not have data *at the firm level* on the R&D activities of firms other than U.S. MNC subsidiaries in each host country. We therefore construct the R&D dispersion measure only for U.S. MNCs' R&D. While we would ideally construct the measure for all firms in each country, our predictions regarding the dispersion of R&D for U.S. MNC subsidiaries and for non-U.S. firms are the same.

We measure the interfirm dispersion of U.S. MNCs' host country R&D as equal to $1 - \Sigma p_i^2$, where $p_i =$ each subsidiary's proportion of total R&D in the same country and industry as the focal subsidiary by all U.S. MNCs. This measure can range from 0 (extreme concentration of R&D) to 1 (extreme dispersion of R&D).

Subsidiary's local/total sales

This variable is measured as the (lagged) proportion of the subsidiary's total sales revenues which are derived from sales in the host country.

MNC's ownership stake in the subsidiary

This variable is constructed as the (lagged) sum of the MNC's direct and indirect ownership share in the focal subsidiary.

Increase in the MNC's ownership stake

This is a dummy variable which equals 1 if the MNC's ownership stake in the focal subsidiary

subsidiary might appear to be 'assigned' R&D as an artifact of the data. For example, consider the following scenario: there are two subsidiaries of the same MNC in the same country—one with R&D and the other without. The subsidiaries are reported separately because they have different industry codes or are unrelated in terms of economic activity. In a given year, the subsidiaries are combined, due either to a reclassification of their industry codes or a merging of their economic activity. This combining results in the subsidiary that previously had no R&D appearing to have been assigned R&D. Although this hypothetical scenario is possible, we checked the data carefully to make sure that R&D assignments did not correspond to industry changes or large changes in the economic activity of the focal subsidiary. We also deal with this problem by estimating static models of R&D status differences and R&D intensity that do not rely on a potentially arbitrary 'assignment' classification. A scenario similar to the above would arise if an existing subsidiary with no R&D is involved in a merger with another company with R&D. Again, the static models of R&D status and R&D intensity abstract over the timing and process of the R&D assignment.

[5] All dollar values are deflated using the U.S. Producer Price Index (1982 = 100). All BEA data are reported in current U.S. dollars. The OECD data were converted to U.S. dollars using nominal exchange rates.

[6] Note that in the economics literature it is common to measure R&D spillovers using R&D 'stock' variables. These are created by transforming R&D flows to stocks using a perpetual inventory method to 'capitalize' the R&D flows. In earlier specifications not reported here, we used R&D stock variables and obtained substantially similar results to those reported using the flow variables described above. Not surprisingly, the correlation between stocks and flows is quite high. We chose to use flows rather than stocks in our final specifications due to the many different countries and industries in our study. The use of R&D stocks would have required imposing rules about R&D depreciation rates across these very different contexts.

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increases between time $t-1$ and time t. Otherwise, it is zero.

MNC's cross-border intrafirm trade

This variable is measured as the (lagged) sum of exports and imports between the MNC's U.S. operations and its foreign subsidiaries divided by the total sales of the U.S. operations.

Number of the MNC's foreign R&D units

This variable is the (lagged) count of the MNC's foreign subsidiaries which already have R&D responsibilities. We also include the square of this variable to test for an inverted-U shaped relationship between this variable and PROB-R&D.

Control variables

Country and industry controls

To obtain better estimates of the effect of potential spillovers from the host country R&D activities of other firms, we needed to control for the confounding effects of country characteristics such as local demand, factor endowments, the presence of a research university, industry competitive factors, etc. In a multi-country, multi-industry research design, it is likely that if country and industry effects are not controlled for estimates of the effects of spillover opportunities could be biased up (see Heckman, 1981). If the characteristics of a country (such as the quality of its education system), or the characteristics of an industry (such as the need for certain natural resources, degree of regulation, competition, or technological sophistication) are the real causes of other MNCs' decisions to do R&D in country c, and are also the primary determinant of the focal MNC's decision to assign R&D responsibilities to subsidiary i, the failure to control for these characteristics will likely generate an observed spurious correlation between other MNCs' R&D and PROB-R&D. Because we cannot control for all possible country and industry characteristics that could potentially cause this problem, we choose instead to include in our model country and industry fixed effects (dummy variables). We also include year dummies to pick up the effects of changes in demand, growth, public policy, and other unobserved time-related variation. Finally, our panel data estimator also controls for subsidiary effects.

Subsidiary and MNC-level controls

We control for the subsidiary's lagged sales (*Subsidiary sales*) using a log transformation, and the lagged total sales of the MNC (*MNC sales*) which is the sum of the sales of the MNC's U.S. operations and sales of all foreign subsidiaries. This variable is also log-transformed.[7]

Estimation

The basic regression model used in this analysis is as follows:

$$Y_{ict} = \beta o + \beta X_{it-1} + \Gamma Z_{jct-1} + \tau_t + \mu + \nu_{it}$$

where Y_{ict} is PROB-R&D and X_{it-1} contains the subsidiary-level and MNC-level predictor and control variables. ΓZ_{jct-1} contains the country–industry R&D of other U.S. MNCs as well as non-U.S. firms and the interfirm dispersion of other U.S. MNCs' R&D. μ contains the time-invariant country and industry fixed effects, and τ_t are the year dummies. ν_{it} is the error term, which is equal to $u_i + \varepsilon_{it}$. The u_i are time-invariant subsidiary-specific characteristics ('firm effects') which are distributed $N(0, \sigma_u^2)$ and are independent and identically distributed over time and across firms. ε_{it}, the random error, is assumed to vary over time and across firms.

Since our dependent variable is discrete, we estimate our regression model as a random effects logit. While a random effects panel data estimator violates the criterion of strict exogeneity in the context of our current model (since we use firm-specific variables as regressors), our choice of estimator was motivated by the desire to include in our sample both subsidiaries that were assigned R&D and subsidiaries that were not. In contrast, a fixed-effects logit sample can include only those subsidiaries that change their R&D status (i.e., subsidiaries that were assigned R&D). We use all lagged independent variables and acknowledge

[7] Two additional control variables (parent MNC's U.S. R&D/sales ratio, and parent MNC's ROA) were included in earlier specifications. However, since these two variables were consistently insignificant and their inclusion or exclusion made no difference to the other parameter estimates, they were dropped from the present analysis.

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that this is an imperfect but commonly used technique for 'exogenizing' firm-specific regressors when estimating panel data regression models.[8,9]

RESULTS

Table 1 presents the descriptive statistics and the correlation matrix for the regression variables. In this table, the means and standard deviations are based on the full sample of subsidiary–year observations. However, for simplicity, we report the correlations for only 1 year, 1993, which has a slightly larger than average number of observations (n for 1993 = 351, n for average year = 330). The correlations do not differ significantly when other years are used. As can be seen, there appear to be no serious multicollinearity problems. No correlations are greater than 0.5. As can also be seen, parent MNCs have, on average, about 10 foreign R&D units. The average subsidiary earns nearly 62 percent of revenues from sales in the local market. Also, parent MNCs have, on average, a 98 percent ownership stake in the subsidiaries. Nonetheless, in 2 percent of the cases, (i.e., 46 cases) parents increased their ownership stake even further during the period under study.

To illustrate some features of our sample, Figure 1 depicts the distribution of new R&D assignments by industry and, within one industry (scientific equipment), by country. Several interesting aspects of U.S. MNCs' global R&D are evident. For example, there are significant differences in the industries that are most R&D intensive and the industries that have the highest proportion of total R&D assignments (note that the latter should be examined relative to each industry's proportion of total observations in the sample, as indicated by the second bar in Figure 1a). Pharmaceuticals, computers, and transportation are the most R&D-intensive industries, but are not among the industries with a relatively high proportion of R&D assignments. It seems likely that the highest R&D-intensive industries have a longer history of global R&D than industries in which new global R&D assignments are being made.

Figure 2 gives the average subsidiary's R&D intensity first by industry and then, within one industry (scientific equipment), by country in 1990. These figures are created from a different sample from Figure 1 (see the subsection 'R&D assignments, status differences, or level?' in the 'Robustness analyses' section). Figure 2(a) shows the striking variation in R&D intensity by industry in 1990. Figure 2(b) compares each country's overall R&D intensity with its R&D intensity in the scientific equipment industry. Observe that Belgium, Germany, Italy and the United Kingdom are the most R&D-intensive countries in scientific equipment. Indeed, Italian affiliates are nearly twice as R&D-intensive in scientific equipment as they are across all industries. However, Italy's proportion of R&D assignments in the scientific equipment industry (from Figure 1b) is smaller than its proportion of R&D assignments across all industries. These charts indicate quite clearly the presence of significant differences across countries and industries. They are also consistent with the observations of Archibugi and Pianta (1992), Cantwell (1993), Frost (2001), Furman *et al*. (2002), and Storper (1992) that, in terms of R&D investments, different countries tend to specialize in different industries.

Table 2 contains the random effects logit results for all hypotheses on the dependent variable PROB-R&D. The bottom four lines of Table 2 under the regression results indicate the following: first, the regression model was estimated with country, industry, and year dummy variables (which are not shown individually, as they can only be interpreted relative to omitted dummies in each category). As indicated in the footnote

[8] A key consideration in our estimation strategy is that the data are truncated on the left side. Additionally, given a general lack of information on the founding of the subsidiaries in our sample there is often no justification for assuming that a subsidiary is 'new' at the time it appears in the sample. Thus, our data are not appropriate for modeling R&D assignments using an event history analysis (Tuma and Hannan, 1984).

[9] In most contexts, using lagged firm-specific regressors in panel data regression models violates the criterion of strict exogeneity (see Keane and Runkle, 1992). Even if we were to use a fixed-effects panel data estimator (or estimated a model in first differences), the firm-specific lagged variables would still not be strictly exogenous if one assumes that firms learn or act with foresight. If learning occurs, then there is a correlation between the contemporaneous error term, ε_{it}, and the lagged firm variables, since current behavior is a function of past behavior if firms learn. Similarly, if firms act with foresight, then future behavior is correlated with current behavior (e.g., sales in $(t+1)$ might be correlated with the error term in time t) and strict exogeneity is violated. Thus, no panel data estimator really allow us to get around this problem. If the goal were to estimate a model that does not violate the criterion of strict exogeneity, it would be unrealistic to include any firm-specific variables as regressors, unless we were to use very long time lags. Unfortunately, our data do not allow us to estimate such a model.

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Table 1. Descriptive statistics and correlation matrix

	Mean (S.D.)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Non-U.S. firms' host country R&D	1.22×10^6 (1.94×10^6)										
(2) U.S. MNCs' host country R&D	63818 (157727)	0.500*									
(3) Interfirm dispersion of U.S. MNCs' host country R&D	0.66 (0.23)	0.311*	0.358*								
(4) Subsidiary's local/total sales	0.62 (0.36)	0.064	0.002	0.047							
(5) MNC's ownership stake in the subsidiary	97.77 (8.46)	−0.100	0.004	−0.029	−0.005						
(6) Increase in the MNC's ownership stake	0.02 (0.14)	0.021	−0.058	0.030	0.000	−0.212*					
(7) MNC (parent's) cross-border intrafirm trade/sales	0.10 (0.10)	0.101	0.034	−0.068	−0.214*	−0.166*	0.036				
(8) # of MNC's foreign R&D units	9.80 (15.09)	−0.062	0.011	0.005	0.045	−0.034	0.036	−0.109			
(9) Subsidiary sales	178990 (727986)	0.035	0.045	−0.009	−0.296*	−0.084	0.045	0.100	−0.067		
(10) MNC sales	1.53×10^7 (3.51×10^7)	0.043	0.101	−0.054	−0.179*	−0.154*	0.075	0.037	0.452*	0.260*	

* $p < 0.01$
For descriptive statistics, subsidiary–year observations = 2306. For the correlation matrix, data are for 1993 only ($n = 351$).
Variables 1, 2, 9, and 10 are in 000's of 1982 (PPI) U.S. dollars.

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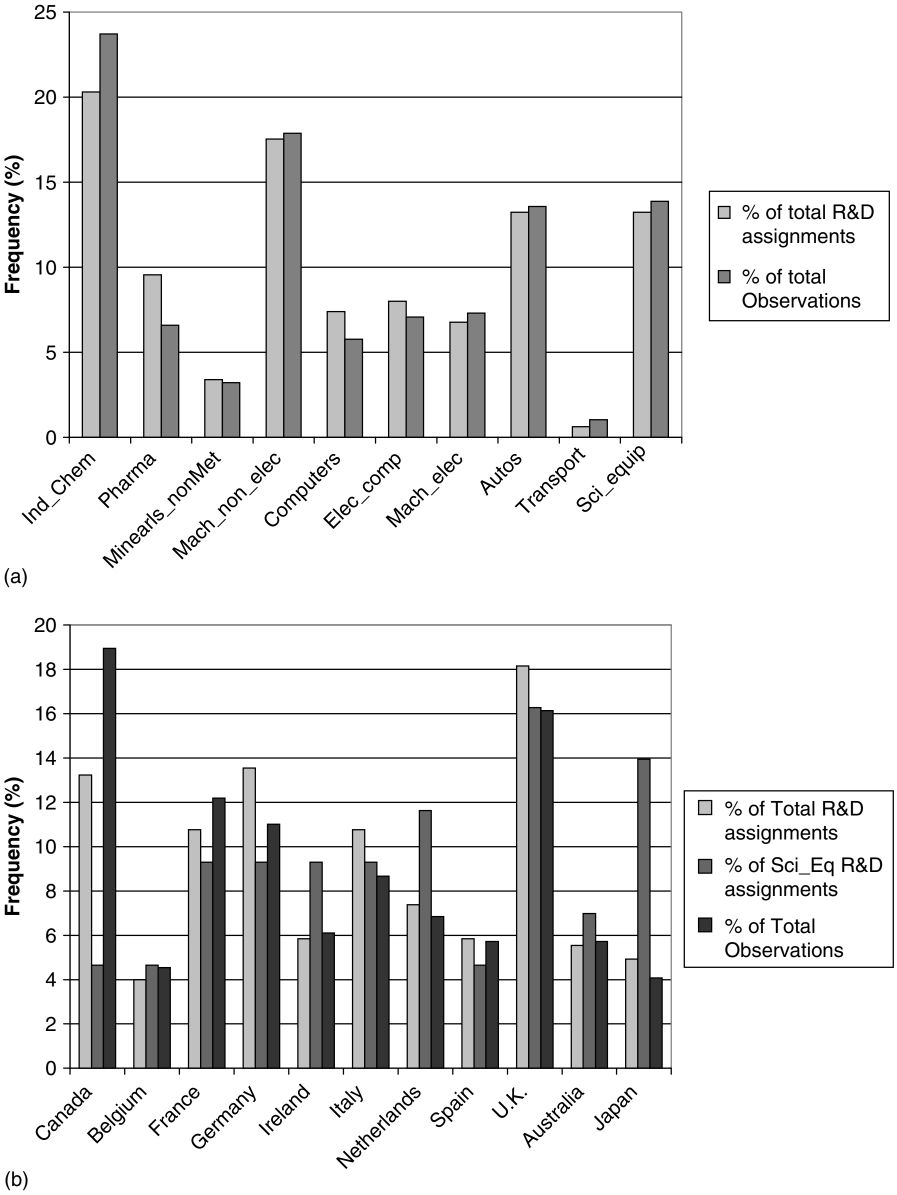

Figure 1. (a) R&D assignments by industry, 1990–96. (b) R&D assignments in the scientific equipment industry, 1990–96

to the table, the likelihood ratio test statistic for the joint significance of these control variables was $\kappa^2 = 40.97$ ($p < 0.05$). As expected, the impact of country, industry, and year controls on PROB-R&D is significant. Next, we give the Wald χ^2 test for the fit of the regression model, and below that we give the number of subsidiary–year observations and the number of subsidiaries, respectively.

Not surprisingly, larger subsidiaries are more likely to be assigned R&D responsibility. Subsidiary sales are positive and significant at the 5 percent level. Interestingly, however, at the MNC level, it is the smaller MNCs which appear more likely to assign R&D responsibility to an existing subsidiary, although this result is only marginally significant.

Focusing now on the tests of the hypotheses, we can see from Table 2 that, of the eight hypotheses (including the two parts of Hypothesis 5), six are supported while two are not.

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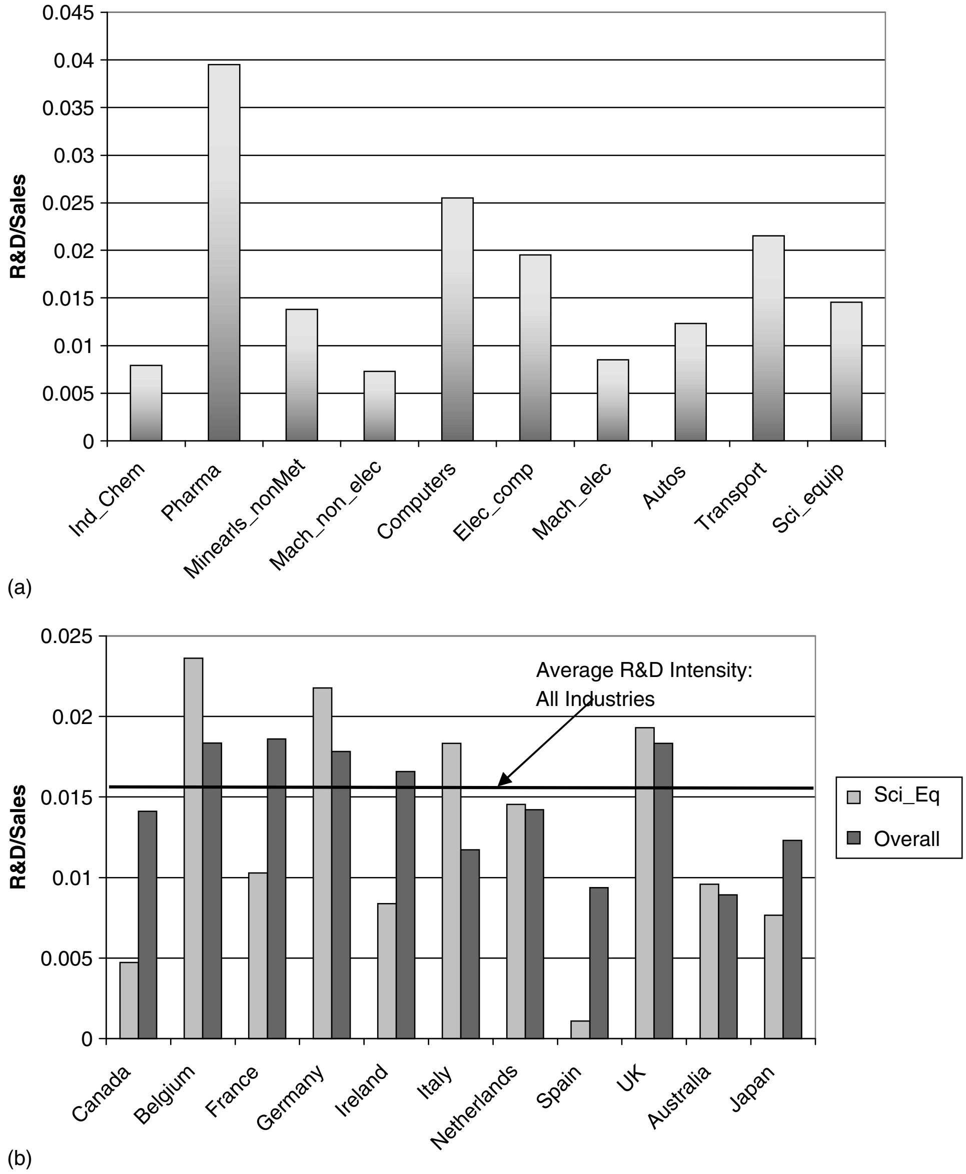

Figure 2. (a) R&D intensity by industry (OECD): 1990. (b) R&D intensity by country, overall and in the scientific equipment industry: 1990

Effects of host country spillover opportunities

Host country R&D by *non-U.S. firms* has no effect on the probability of a subsidiary being assigned R&D. However, host country R&D by other same-industry *U.S. MNCs* has the predicted positive effect on PROB-R&D and is significant at the 5 percent level. Thus, Hypothesis 1 is supported for U.S. MNCs' host country R&D but not for the R&D of non-U.S. firms. Interestingly, in the model without country, industry and year dummies, both spillover variables were significant and positive. However, with the addition of controls for country, industry, and time, spillovers from U.S. MNCs become more significant whereas spillovers from non-U.S. firms become insignificant. At the end of this section, we conduct some additional exploratory analyses to examine the spillover results in more detail. Specifically, we test for the possibility that the MNC R&D variable may really be picking up herding effects, rather than the potential for knowledge spillovers.

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Table 2. Random effects logit model for PROB-R&D

Variable	Hyp.	Estimate (S.E.)
Non-U.S. firms' host country R&D	H1 (+)	0.069 (0.150)
Other U.S. MNCs' host country R&D	H1 (+)	0.184** (0.086)
Interfirm dispersion of U.S. MNCs' host country R&D	H2 (+)	3.030** (1.353)
Other U.S. MNCs' host country R&D* interfirm dispersion	H3 (−)	−0.340** (0.134)
Subsidiary local/total sales	H4 (+)	0.115 (0.236)
MNC's ownership stake in the subsidiary	H5a (+)	0.000 (0.001)
Increase in the MNC's ownership stake	H5b (+)	1.094** (0.434)
MNC's cross-border intrafirm trade	H6 (+)	1.183* (0.662)
# of MNC's foreign R&D units	H7 (+)	0.066*** (0.014)
(# of MNC's foreign R&D units)^2	H7 (−)	−0.001*** (0.000)
Subsidiary sales		0.144** (0.058)
MNC foreign sales		−0.063* (0.031)
Constant		−5.650 (3.894)
Firm effect ($\sigma^2_{ui}/\sigma^2_{ui} + 1$)		0.374** (0.151)
Country, industry, year effects		YES
χ^2 model		83.87***
Number of observations		2306
Number of subsidiaries		989

*** $p < 0.01$, ** $p < 0.5$, * $p < 0.1$. All t tests are 2-tailed.
The likelihood ratio test statistic for the joint significance of the country, industry and year effects is 40.97**.
The log-likelihood for the model is −891.92.

We find strong support for Hypotheses 2 and 3, in the predicted directions. Indicating support for Hypothesis 2, greater dispersion of other U.S. MNCs' host country R&D is positively associated with the probability that a subsidiary will be assigned R&D responsibilities. Finally, as predicted in Hypothesis 3, the effect of other U.S. MNCs' host country R&D dispersion is moderated by the magnitude of the MNCs' host country R&D, as indicated by the significant negative interaction.

Effects of MNC capacity for local utilization

As predicted in Hypothesis 4, if an MNC's primary motive for assigning R&D to foreign subsidiaries were to adapt products to local markets, we would expect that a subsidiary's ratio of local/total sales would be positively associated with the probability of that subsidiary being assigned R&D responsibilities. However, we find no support for this hypothesis.

Effects of MNC capacity for global utilization

MNC's ability to appropriate the subsidiary's technical knowledge

Contrary to expectations, we did not find support for Hypothesis 5a—the MNC's ownership stake in the focal subsidiary has no effect on the probability of the subsidiary being assigned R&D responsibilities. However, we find support for Hypothesis 5b—an increase in the MNC's ownership stake does have the predicted positive effect on R&D assignment. The most likely explanation for the

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lack of support for Hypothesis 5a is the fact that, with an average ownership stake of 98 percent, there is very little variation in this variable. Indeed, because minority-owned subsidiaries do not report data on the location of sales (e.g., local, within the MNC), we removed them from the sample altogether. Nonetheless, the support for Hypothesis 5b is important because it indicates that, when MNCs decide to assign R&D responsibility to a foreign subsidiary, they also act to increase their expected ability to appropriate knowledge from that R&D by raising their ownership stake in the subsidiary.

MNC's organizational ability to transfer the subsidiary's knowledge

We find support at the 10 percent level for Hypothesis 6: subsidiaries of MNC parents with a greater proportion of intrafirm trade/total sales are more likely to be assigned R&D responsibilities. Because intrafirm trade in goods indicates established linkages within the MNC, and goods embody the R&D in the production process, we view this result as important, despite its weak significance.

On the other hand, we find strong support for Hypothesis 7—subsidiaries of MNCs with a larger number of existing foreign R&D units are more likely to be assigned R&D. As predicted, the relationship between the number of existing R&D units that an MNC has and the probability that the MNC will assign R&D to the focal subsidiary has an inverted-U shape. A larger number of existing foreign R&D units suggests the presence of more developed organizational mechanisms within the MNC to transfer knowledge. However, there appears to be a saturation level of foreign R&D units for MNCs, as increasingly large numbers of foreign R&D subsidiaries eventually reduce the likelihood that additional subsidiaries will be assigned R&D. Note that the calculated inflection point for the squared term is 33 R&D units. While this value is more than one standard deviation from the mean number of R&D units for MNCs with at least one R&D unit, it is between the 90th and 95th percentile in terms of number of R&D units.

ROBUSTNESS ANALYSES

Although the country, industry, and time dummy variables in our model should pick up many important unobserved effects that could bias our results, we conducted some additional exploratory analyses to gain further insight into the relationships that we test in Hypotheses 1–7. We present the results of these analyses and discussion below.

Spillovers or herding?

Despite our expectation that county and industry effects would capture unobserved herding processes within industries, it is nevertheless possible that the significant coefficient on the MNC R&D variable could really be capturing this phenomenon. To attempt to rule out herding as an explanation for our results, we created two additional variables to measure herding effects.

First, the (lagged) count of competitors' R&D subsidiaries in the same country–industry as the focal subsidiary captures the 'stock' of R&D units that the MNC's competitors have located in the host country in prior years. However, because herding involves both stocks and flows, we also take into account the number of new MNC R&D units in the focal subsidiary's industry in the host country from $t-1$ to t (the 'flow'). Similar to the spillover variables, both herding variables were calculated out-of-sample, using the population of subsidiary data (to capture all U.S. MNC R&D activity in each country). Since we have relatively few years of data to work with, we were constrained in our ability to use longer lags. Additionally, we believe that the appropriate number of lags in an R&D location herding process is an open empirical question, and one beyond the scope of this paper. Our analyses are exploratory, but suggestive.

Table 3 reports the results of our tests for herding. In the first column, we run the random-effects logit model for PROB-R&D excluding the R&D size and R&D dispersion variables but including the two herding variables. Neither herding variable is significant.[10] Although the spillover variables have been removed and the herding variables are insignificant, note how similar the estimates and standard errors of all the subsidiary- and MNC-specific variables are to the base estimates in Table 2. Thus, it seems reasonable to conclude that

[10] In another specification not reported here, we created a third herding variable—an interaction of the stock and flow variables described above and ran the model in column 1 with the three variables. None were significant and the other results were unaffected.

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Table 3. Random effects logit estimates for Prob-R&D with controls for herding

Variable	Hyp.	Herding only	Base+ Herding	Base+ count	Base+ new R&D subs
Non-U.S. firms' host country R&D	H1 (+)		0.095	0.086	0.079
			(0.150)	(0.150)	(0.150)
Other U.S. MNCs' host country R&D	H1 (+)		0.186**	0.176**	0.194**
			(0.086)	(0.086)	(0.087)
Interfirm dispersion of U.S. MNCs' host country R&D	H2 (+)		3.689***	3.487**	3.255**
			(1.391)	(1.384)	(1.362)
Other U.S. MNCs' host country R&D* interfirm dispersion	H3 (−)		−0.414***	−0.395***	−0.361***
			(0.139)	(0.139)	(0.135)
Count of R&D subsidiaries in host country–industry		0.005	0.009	0.010	
		(0.006)	(0.006)	(0.006)	
New R&D subsidiaries in host country–industry		−0.059	−0.071		−0.073
		(0.048)	(0.048)		(0.048)
Subsidiary local/total sales	H4 (+)	0.154	0.124	0.113	0.126
		(0.239)	(0.234)	(0.236)	(0.235)
MNC's ownership stake in the subsidiary	H5a (+)	0.000	0.000	0.000	0.000
		(0.001)	(0.001)	(0.001)	(0.001)
Increase in the MNC's ownership stake	H5b (+)	1.164***	1.159**	1.105**	1.151***
		(0.442)	(0.433)	(0.433)	(0.434)
MNC's cross-border intrafirm trade	H6 (+)	1.259*	1.244*	1.239*	1.191*
		(0.671)	(0.657)	(0.661)	(0.658)
# of MNC's foreign R&D units	H7 (+)	0.069***	0.069***	0.068***	0.067***
		(0.015)	(0.014)	(0.014)	(0.014)
(# of MNC's foreign R&D units)^2	H7 (−)	−0.001***	−0.001***	−0.001***	−0.001***
		(0.000)	(0.000)	(0.000)	(0.000)
Subsidiary sales		0.146**	0.140**	0.141**	0.143**
		(0.058)	(0.057)	(0.057)	(0.058)
MNC foreign sales		−0.066**	−0.064**	−0.063**	−0.064**
		(0.031)	(0.030)	(0.031)	(0.031)
Constant		−2.127	−6.341*	−6.114*	−6.172*
		(1.590)	(3.246)	(3.254)	(3.247)
Firm effect $(\sigma^2_{ui}/\sigma^2_{ui}+1)$		0.403***	0.351**	0.364**	0.360**
		(0.146)	(0.156)	(0.152)	(0.155)
Country, industry, year effects		YES	YES	YES	YES
χ^2 model		77.65***	88.53***	86.15***	86.29***
Number of observations		2306	2306	2306	2306
Number of subsidiaries		989	989	989	989

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. All t tests are 2-tailed.

these results are robust to the inclusion or exclusion of herding effects and spillovers.

Columns 2–4 in Table 3 present estimates of the base model with all spillover variables and both herding variables, counts ('stocks') only, and new R&D subsidiaries ('flows') only, respectively. Again, none of the herding variables are significant in any of these specifications, and all of the spillover variables that were significant in the base specification remain significant. Similar to the MNC variables in column 1, the spillover estimates and standard errors in columns 2–4 are strikingly similar to each other and to the base estimates in Table 2. The MNC variables remain consistent across all the estimates. Although our measurements of herding are somewhat rough, the robustness of the other results and the consistent lack of support for the herding variables across specifications lend confidence to our interpretation of the MNC R&D variables as depicting potential spillovers rather than herding effects. If the MNC R&D variables were capturing herding, we would

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expect to see the spillover variables lose significance with the inclusion of the herding variables. This is not borne out in the results in Table 3.

R&D assignments, status differences, or level?

We also examine issues related to the robustness of the sample and the random-effects logit model. We look at whether our results are robust to estimating the model on a cross-section of subsidiaries drawn from the entire population in a single year. Here, we do not limit the sample to subsidiaries with at least two consecutive observations, the first with no subsidiary R&D. We simply do two static estimations, a logit and tobit. These can be interpreted as examining the correlates of subsidiary R&D status (static logit) and subsidiary R&D intensity (static tobit), respectively. The results of these models are shown in Table 4 for 1990.

The criteria for including subsidiaries in the static sample were the following. First, a subsidiary had to report data (rather than having estimated data). Second, a subsidiary had to be in one of the OECD–country–industry groups for which we had domestic R&D spillover data. The static sample includes the same 10 industries as the panel. However, the results in Table 4 include data from the Nordic countries that were eliminated from the panel due to insufficient consecutive observations that met the sampling criteria. Third, a subsidiary had to be majority-owned, because minority-owned subsidiaries do not report location-of-sales data (and, thus, would have prevented us from calculating subsidiary local/total

Table 4. Logit and tobit estimates for R&D status and R&D intensity in 1990

Variable	Hyp.	R&D status (logit: 1, 0)	R&D intensity (tobit: R&D/sales)
Non-U.S. firms' host country R&D	H1 (+)	0.084	0.000
		(0.148)	(0.003)
Other U.S. MNCs' host country R&D	H1 (+)	0.211**	0.005***
		(0.085)	(0.002)
Interfirm dispersion of U.S. MNCs' host country R&D	H2 (+)	2.167	0.014
		(1.611)	(0.032)
Other U.S. MNCs' host country R&D* interfirm dispersion	H3 (−)	−0.207	−0.001
		(0.163)	(0.003)
Subsidiary local/total sales	H4 (+)	0.095	−0.003
		(0.253)	(0.005)
MNC's ownership stake in the subsidiary	H5a (+)	0.000	0.000
		(0.001)	(0.000)
Increase in the MNC's ownership stake	H5b (−)	0.146	0.012
		(0.585)	(0.012)
MNC's cross-border intrafirm trade	H6 (+)	0.289	0.016
		(0.753)	(0.016)
# of MNC's foreign R&D units	H7 (+)	0.170***	0.002***
		(0.019)	(0.000)
(# of MNC's foreign R&D units)^2	H7 (−)	−0.002***	−0.000***
		(0.000)	(0.000)
Subsidiary sales		0.590***	0.007***
		(0.076)	(0.001)
MNC foreign sales		−0.537***	−0.006***
		(0.068)	(0.001)
Constant		−3.161	−0.030
		(3.153)	(0.064)
Standard error			0.044***
			(0.001)
Country, industry effects		YES	YES
χ^2 Model		278.93***	237.47***
Number of observations		1135	1135

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$
All t-tests are 2-tailed. The log-likelihood for the logit is 621.9. The log-likelihood for the tobit is 897.51. In the tobit, 450 observations are equal to zero.

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sales). After screening the 1990 data for these criteria, we were left with a sample of 1135 subsidiaries of 368 U.S. parents. The dependent variable in the static logit, *R&D Status*, is 1 if a subsidiary has R&D in 1990, and 0 otherwise. The dependent variable in the tobit, *R&D Intensity*, is the subsidiary's R&D/sales ratio in 1990.

Before discussing the results in Table 4, we note that our main expectation with regard to the static logit and tobit was that the country–industry-level variables would have a weaker effect on both subsidiary R&D status and R&D intensity. Because decisions about R&D intensity are operating decisions as opposed to larger strategic decisions—such as the decision to assign new R&D responsibilities—we expected the firm-specific variables to be more significant and the country–industry variables to be less significant in the static models.[11] Note that, similar to the panel regressions, the static models include country and industry dummy variables.

Since the models are static, the logit and tobit analyses should yield very similar results. Subsidiaries with some R&D should be different from subsidiaries with no R&D. This would be captured in the logit and the tobit. The tobit simply provides some additional information about the relationship between the independent variables and the subsidiary's actual R&D intensity.

As can be seen in Table 4 (columns 1–2), the results of the static analyses met some of our expectations. For example, the MNC spillover variable (i.e., level of other U.S. MNCs' host country R&D) remains positive and significant in both the logit and the tobit, but none of the R&D dispersion variables are significant. By contrast, two firm-specific variables that were significant in the panel regression (MNC's cross-border intrafirm trade, and an increase in the MNC's ownership stake in the subsidiary) are insignificant in both static regressions. The intrafirm trade variable was only marginally significant in the panel regression, and the increase in ownership stake has so little variance in the static model that the loss of its significance is not surprising.

The static models add robustness to our overall analyses on several dimensions. They address some of the potential data classification issues in the panel sample discussed in footnote 4. Note that we do not know if the subsidiaries in the static sample had R&D in the previous year, or in every year that they appear in the sample. We make no assumptions about the process by which the subsidiaries' R&D status or intensity varies in 1990. However, the significance of the MNC spillover variable—despite our expectation of weaker country effects—and the significant curvilinear relationship between an MNC's existing count of foreign R&D units and the R&D status (intensity) of the focal subsidiary give additional support for the predictions of the panel data analysis of R&D assignments.

[11] As an analogy, consider a university's decision to add a brand new department as compared with its decision to change the number of faculty lines in an already existing department. As appears obvious, while both decisions are resource allocation decisions, the former is far more strategic than the latter.

DISCUSSION

In this paper, we advanced a theoretical framework and set of hypotheses rooted in the argument that MNCs' decisions to assign new R&D responsibilities to existing foreign subsidiaries would be significantly and systematically influenced by the nature of the R&D spillover opportunities present in the host country, and the MNCs' local and global capacity to utilize knowledge accumulated by their foreign subsidiaries. We tested these hypotheses using disaggregated panel data from the BEA for the time period 1989–96. Our sample comprised 2306 affiliate–year observations on 989 affiliates of 361 U.S. MNC parents. All of these affiliates were located in 11 OECD countries, operated in industries with above-average R&D intensity, and were majority owned by their U.S. parents.

Our findings suggest that, when deciding whether or not to assign R&D responsibilities to an existing subsidiary, country and industry characteristics do matter. However, potential knowledge spillover opportunities are also highly salient. MNCs not only anticipate the likelihood of knowledge spillovers from other firms, but they also appear to discriminate between different types of firms in assessing the potential for spillovers. More specifically, U.S. MNCs appear to view spillovers from host country subsidiaries of other same-industry U.S. MNCs as either more likely and/or more relevant than spillovers from non-U.S. firms in the same industry and host country. U.S. MNCs also appear to view spillovers as more likely when, controlling for scale, the host country

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R&D activities of same-industry U.S. MNCs are more widely dispersed across a larger number of firms. Finally, they appear to anticipate a certain degree of substitutability between spillover potential resulting from the total scale of other U.S. MNCs' local R&D vs. that resulting from greater R&D dispersion. Our tests regarding the possibility of herding behavior which may also drive firms to gravitate towards R&D clusters populated by other same-industry firms yielded no significant results. Thus, the salience of knowledge spillovers to global R&D assignments appears robust to alternative explanations.

In addition to knowledge spillover opportunities, MNCs' decisions regarding the assignment of R&D responsibilities to foreign subsidiaries also appear to be based heavily on the MNCs' capacity to utilize the internally created or externally acquired technologies globally. MNCs appear to value their ability to *appropriate* the newly acquired technologies and to *transfer* these technologies to the rest of the global network. The likelihood of a subsidiary being assigned R&D responsibilities is greater when the parent increases its ownership stake in the subsidiary during the previous year as well as when it engages in greater cross-border intrafirm trade. Our analyses also reveal the existence of an inverted U-shaped relationship between number of foreign R&D units that the MNC has already established and the probability that it will assign R&D to an additional subsidiary. The establishment of foreign R&D units in the past increases the MNC's ability to leverage its technology assets globally and, up to a point, has a positive impact on its willingness to set up additional R&D units. However, if the MNC already has a large number of foreign R&D units, then the addition of new R&D units starts to become unattractive. In contrast to global utilization capacity, we did not find support for expectations that the subsidiary's local utilization capacity would have a significant effect on the likelihood of its being assigned R&D responsibilities. A potential explanation would be that our sample consists only of those MNCs which operate in industries with above-average R&D intensity. MNCs in such industries may have greater incentives as well as more developed routines to transfer and deploy subsidiary-level technical knowledge on a global basis. Thus, the importance of local utilization may be more pronounced in the case of MNCs from less R&D-intensive industries.

Taken together, our results extend the literature on MNCs' R&D location decisions in a significant new direction. Consistent with past research regarding the salience of host country factor endowments, we find that country and industry effects do matter. However, we also find that the potential to capture and utilize knowledge spillovers from competitors' R&D activities also matters. Our results support and reinforce our theoretical arguments that MNCs view the assignment of R&D responsibilities to a subsidiary as an investment in the subsidiary's capacity not only to *create* new technical knowledge through internal efforts but also to *absorb* spillovers of external knowledge from competitors' R&D activities. In other words, absorption of external knowledge is not just an intended by-product of assigning R&D responsibilities to a subsidiary; rather, such absorption appears to be anticipated and factored in by MNC executives making R&D location decisions.

We now highlight some of the more promising directions for future research on the role of knowledge spillovers in MNCs' R&D location decisions. First, in this study, we considered only some of the firm-specific characteristics that may drive MNCs' incentives and ability to capture spillovers. Other potentially salient firm characteristics merit investigation. For example, might MNCs that are R&D laggards in their industries have greater incentives to close the R&D gap by absorbing knowledge spillovers from their competitors as compared with MNCs that are R&D leaders? If so, then the same spillover opportunity may have greater salience for R&D laggards than for R&D leaders. The salience of knowledge spillover opportunities may also be different for MNCs embedded in low vs. high R&D-intensity industries. For obvious reasons, we can expect firms in R&D-intensive industries to place greater value on accumulation of technical knowledge. Thus, might the same level of spillover opportunity have greater salience for MNCs in more or less R&D-intensive industries? In terms of ability to capture spillovers, it can be argued that subsidiaries that are more prone to taking entrepreneurial initiative (Birkinshaw and Hood, 1998) may be more active in building interfirm networks and thus have a more developed ability to capture spillovers. It is not unlikely that, at the time of deciding which subsidiary should be assigned new R&D responsibilities, corporate executives may also take into account the track record of subsidiary managers

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at taking entrepreneurial initiative. These issues, unaddressed in the present study, appear salient for future research.

Another interesting avenue for future research pertains to potential herding effects. In this study, our exploratory tests for herding as an explanation for R&D assignments were insignificant. However, given the weight of past evidence regarding the widespread presence of institutional pressures for mimetic isomorphism (DiMaggio and Powell, 1983), we cannot entirely dismiss the potential role of herding behavior in MNCs' R&D location decisions. Might there be some types of industry- and firm-level contexts that may make some MNCs more prone to herding behavior than others? For example, might firms in less R&D-intensive industries and/or firms with lower levels of performance relative to their competitors be more prone to herding behavior?

Yet another interesting direction for future research would be to examine the salience of spillover effects at various levels of *industry* aggregation. In the BEA data, foreign affiliates report sales only at the three-digit industry level; thus, we were prevented from testing spillover effects at finer (e.g., four-digit) levels of industry aggregation. As noted by Frost (2001) and Porter and Stern (2001), knowledge spillovers include not only competitive but also complementary ideas. While analysis at a four-digit industry level may conceivably capture the effects of potential competitive spillovers more accurately, analysis at the three-digit industry level may be more likely to also capture the effects of potential complementary spillovers. In analyses not presented here, within the bounds of the BEA data, we explored whether the level of industry aggregation makes a difference. Specifically, we examined whether the observed significance of potential knowledge spillovers is different at the three-digit vs. two-digit level of aggregation. Our results showed significant spillover effects from MNCs' R&D at the three-digit but not at the two-digit level of aggregation. These analyses support the idea that the level of industry aggregation matters. However, our study has left the question of what would be the optimal level of industry aggregation unaddressed.

An interesting direction for future research would also be to examine the salience of spillover effects at various levels of *geographic* aggregation. In its examination of spillover effects, this study focused on the country as the unit of analysis rather than a smaller sub-national economic area. This limitation is salient because literature on spillover effects has identified the sub-national area (e.g., Oxbridge rather than the United Kingdom as a whole) as the most appropriate level of analysis (Almeida, 1996; Frost, 2001; Jaffe *et al*., 1993). On this issue, we were constrained by the fact that the BEA and OECD data are available only at the country level. Our study leaves unaddressed the question of what the results might be like if we were to examine finer or coarser levels of geographic aggregation or if we were to focus on non-U.S. companies locating R&D activities within the United States.

We conclude by identifying some additional directions for future research not already discussed above. First, the question of whether spillover opportunities and utilization capacities matter in the globalization of R&D should be examined in contexts omitted by us, viz. non-U.S. MNCs, subsidiaries located in emerging markets, and subsidiaries that are less than majority owned by their parents. Second, in this study, even though we focused on subsidiaries in R&D-intensive industries, we did not undertake the analysis separately for each industry. Examination of cross-industry variation in the existence and salience of spillover opportunities in explaining MNCs' R&D location choices is another promising avenue for future research.

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