

**Is Foreign Direct Investment a Channel of Knowledge Spillovers?  
Evidence from Japan's FDI in the United States\***

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**Abstract**

Recent empirical work has examined the extent to which international trade fosters international “spillovers” of technological information. FDI is an alternate, potentially equally important channel for the mediation of such knowledge spillovers. I introduce a framework for measuring international knowledge spillovers at the *firm* level, and I use this framework to directly test the hypothesis that FDI is a channel of knowledge spillovers for Japanese multinationals undertaking direct investments in the United States. Using an original firm-level panel data set on Japanese firms' FDI and innovative activity, I find evidence that FDI increases the flow of knowledge spillovers both from and to the investing Japanese firms.

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## I. Introduction

To what extent does technological knowledge flow across national borders, and by what means are these knowledge flows mediated? These questions have received an increasing amount of attention over the last decade, as leading scholars in international economics have focused considerable research effort on the topic of knowledge spillovers.<sup>1</sup> A considerable body of theoretical and empirical work has focused on the extent to which imports of manufactured goods could serve as channels of knowledge spillovers.<sup>2</sup> While less thoroughly explored in formal models, the literature also suggests the possibility of a “learning-by-exporting” effect in which firms learn to improve the quality of their products and production processes through contact with more advanced foreign competitors in global export markets.<sup>3</sup>

The flow of goods is not the only means through which technological knowledge can flow across national boundaries. An obvious alternative is foreign direct investment. A number of countries have policies that encourage or even subsidize multinational investment. Often, as has been the case in Singapore and Malaysia, these policies are deliberately biased in favor of multinational firms in “technology intensive” industries. Such preferences are based on the view that production and/or research activities undertaken by multinational affiliates within national borders confer “spillover” benefits. In an effort to submit these views to careful statistical tests, a number of scholars have undertaken empirical studies of spillover benefits from FDI. The work of Harrison and her co-authors, which has been particularly influential, has used micro-level panel data drawn from Morocco and Venezuela.<sup>4</sup> Following

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<sup>1</sup> See the work of Ethier (1982), Rivera-Batiz and Romer (1991), Feenstra (1996), and Grossman and Helpman (1990, 1991) for models of innovation-driven growth and trade.

<sup>2</sup> For empirical work on this possible channel of international knowledge spillovers, see Coe and Helpman (1995), and Keller (1998).

<sup>3</sup> For empirical work on the “learning by exporting” channel, see Bernard and Jensen (1999), Clerides, Lach, and Tybout (1998), Aw, Chen, and Roberts (2001), and MacGarvie (2003). In general, these scholars have failed to find strong evidence of “learning by exporting.”

<sup>4</sup> See Aitken and Harrison (1999) and Haddad and Harrison (1993). A number of other studies, such as Eaton and Tamura (1996), use aggregate or industry-level data to examine these and related issues.

the basic methodology developed by Aitken and Harrison (1999), Keller and Yeaple (2003) and Haskel, Periera, and Slaughter (2002) have examined FDI in advanced industrial economies, and Javorcik (2004) has examined FDI in Lithuania.

In previous work, I have examined issues related to the focus of this paper. Branstetter and Nakamura (2003) examined changes in the research productivity of Japanese manufacturing firms over the 1980s and 1990s. As part of that study, we examined the extent to which R&D alliances and partnerships with U.S. firms facilitated the flow of knowledge spillovers across international boundaries. That paper did *not* examine the role of FDI as a channel of knowledge spillovers. Branstetter (2000) examined the role of FDI as a channel of knowledge spillovers from the U.S. to Japan, but was able to do so only indirectly, by quantifying the comovement between the R&D spending of U.S. firms and the patent output of Japanese corporations. As noted in that paper, these correlations are subject to confounding influences, raising doubts about the accuracy of such indirect inference.

This paper examines the role FDI plays in mediating knowledge spillovers, but it takes a completely different methodological approach. First, in contrast to many of the aforementioned papers, I measure the impact of FDI not only on knowledge spillovers from the investing Japanese firms to “indigenous” American firms, but also the impact of Japanese investment on knowledge spillovers from American firms to the investing Japanese firms.<sup>5</sup> Second, I allow the impact of FDI on knowledge spillovers to depend upon the nature of the subsidiary – and I find differences in the spillover-enhancing impact of different types of subsidiaries that are consistent with recent theoretical work on multinational firms. Third, I do not follow the earlier convention of using measured changes in TFP or other revenue-based measures to infer the presence or absence of knowledge spillovers.

As is well known, conventional measures of productivity can reflect market power as well as technical efficiency.<sup>6</sup> When technologically more advanced foreign affiliates first enter a market, their presence may erode the market power of indigenous incumbents while -- at the same time -- introducing new production techniques and technologies from which these same incumbents learn. Real knowledge

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<sup>5</sup> Iwasa and Odagiri (2004) present results on the impact of Japanese research facilities in the U.S. on the innovative activity of the investing parent firm.

<sup>6</sup> This point has been made by many others, including Bernard, Eaton, Jensen, and Kortum (2003).

spillovers can take place, yet their effects can be masked in the data by changes in appropriability conditions. Alternatively, robust demand growth in a sector of the host country could lead to higher profits, which generates higher measured TFP growth for domestic firms while, at the same time, inducing investment by foreign firms.

This paper presents an alternative empirical framework for measuring the impact of foreign direct investment on knowledge spillovers using patent citations data. I then use this framework to measure the impact of foreign direct investment in the United States by a group of Japanese manufacturing firms on knowledge flows *from* American firms *to* these investing Japanese firms and *from* the investing Japanese firms *to* American inventors. To preview my empirical results, I find evidence that foreign direct investment enhances knowledge flows in both directions. I also find that the direction and degree of spillover flow is related to the characteristics of Japanese firms' U.S. subsidiaries in plausible ways. Knowledge spillovers received *by* the investing Japanese firms tend to be strongest via R&D and product development facilities. On the other hand, spillovers *from* the investing Japanese firms to indigenous American inventors appear to flow most strongly through Japanese firms' greenfield affiliates.

## **II. Empirical Methodology**

### *Using Patent Citations Data to Infer Knowledge Spillovers*

In describing the approach taken in this paper, I need to begin by carefully defining what I mean by the term "knowledge spillovers." When I use this term, I refer to the process by which one inventor learns from the research outcomes of others' research projects and is able to enhance her own research productivity with this knowledge without fully compensating the other inventors for the value of this learning. A true knowledge spillover, by my definition, is something that generates *further innovation*. One can thus make a conceptual distinction between knowledge spillovers and imitation or adoption of existing technology.

In pursuit of such spillovers, it is possible that firms may make conscious investments in their capacity to learn from other firms' research activities. Technically, only the value of knowledge flows that exceeds the cost of such investments would constitute a spillover in the full sense of the word. The methodology used in this paper will allow me to track knowledge flows that lead to subsequent innovation,

but it will not always be possible to identify the “pure” spillover component. Unfortunately, this is a shortcoming common to much of the empirical literature on knowledge spillovers.

Patent documents provide a potentially rich source of information on knowledge spillovers. Every U.S. patent applicant is required to include appropriate citations to the “prior art” in his or her application. By explicitly identifying the prior art on which the inventor builds, these citations serve the important legal function of bounding the innovation protected by the patent document. Just as academic researchers are expected to explicitly acknowledge the ideas and findings of others that they use in their own research (or be open to charges of plagiarism), so patent applicants are expected to identify the prior art on which they build (or be open to charges of patent infringement).<sup>7</sup> By examining the citations in corporate patent documents, one can see the innovations the inventors consider to be the “technological antecedents” of their own inventions.<sup>8</sup>

The legal function citations play in delineating the scope of the intellectual property rights conferred by a patent creates strong incentives for inventors to get the number and nature of citations right. The cost of citing a friend in a scientific paper is minimal, so it may frequently take place even when little or no knowledge spillover has taken place. The cost of extraneous citations in a patent document can be substantial, because they narrow the scope of the patent by explicitly placing related inventions *outside* the scope of the current patent application. As Jaffe, Trajtenberg, and Henderson (1993) put it, including extraneous citations is “leaving money on the table.” Likewise, deliberately excluding appropriate citations can expose a patent applicant to patent infringement lawsuits or to sanctions by the U.S. Patent and Trademark Office.

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<sup>7</sup> This analogy, while illustrative, is far from exact. Jaffe, Fogarty, and Banks (1998) and Fogarty, Jaffe, and Trajtenberg (2000) find that some patent citations are added by parties other than the inventor, such as patent attorneys or the patent examiner, for legal or procedural reasons that have nothing to do with “knowledge spillovers.” Nevertheless, they found evidence that patent citations do indeed reflect patterns of knowledge spillovers.

<sup>8</sup> The points in this paragraph have been made and substantiated by Jaffe and his various co-authors, and some of the language here closely follows Jaffe, Fogarty, and Banks (1998).

The use of patent citations as an indicator of knowledge spillovers has been pioneered by Adam Jaffe, Manuel Trajtenberg, and Rebecca Henderson. In their 1993 paper, these three researchers used patent citations to measure the extent to which knowledge spillovers within the United States are geographically localized. In a series of papers and a recent book, Jaffe and Trajtenberg have used patent citations to compare magnitudes of knowledge flows across countries and across technological fields.<sup>9</sup> This paper uses patent citations to measure the extent to which FDI aids or abets flows of knowledge across national borders.

Other recent work has used patent citation data to examine knowledge flows between domestic innovators and multinational *subsidiaries* in the United States, employing a variant of the methodology introduced in Jaffe, Trajtenberg, and Henderson (1993).<sup>10</sup> This paper differs from that earlier work in two respects.<sup>11</sup> First, the paper links firm-level data on the expanding U.S. affiliate networks of a set of Japanese firms to data on the citations patterns contained in their U.S. patents in a panel data set. This allows me to examine the impact of changes in the U.S. “FDI presence” of individual firms on their citation patterns, controlling for other firm-level characteristics. Second, I examine patent citations not just to and from the patents of the U.S. subsidiaries of my sample firms, but also the patents of the parent companies.<sup>12</sup>

*Estimating the Impact of FDI on Knowledge Spillovers*

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<sup>9</sup> See Jaffe and Trajtenberg (1996, 2002).

<sup>10</sup> Almeida (1996) compared the citation patterns in 114 patents assigned to the U.S. subsidiaries of foreign semiconductor firms to the citation patterns in an equivalent number of patents assigned to U.S. firms. Frost (2001) extended this basic methodology to a much larger data set. Singh (2002) has used matched pairs of “foreign subsidiary” and “domestic” patents to examine citations from foreign subsidiaries to domestic entities, from domestic entities to foreign subsidiaries, and between foreign subsidiaries.

<sup>11</sup> The paper that comes closest to my approach is the study by MacGarvie (2003), who uses an empirical specification closely modeled on Branstetter (2000a) to measure the impact of French firms’ trade flows on knowledge spillovers as measured by the patent citations in *European* patent documents.

<sup>12</sup> Belderbos (2001) shows that throughout the 1980s and 1990s, the innovative activity of Japanese firms’ U.S. subsidiaries was very small compared to the R&D activity of the parent firm, and these subsidiaries accounted for only a small fraction of the parent system’s total U.S. patents (on the order of 3%).

Let  $C_{it}^J$  be the number of citations made by the patent applications Japanese firm  $i$  filed in year  $t$  to the cumulated stock of “indigenous” U.S.-invented patents granted as of year  $t$ .<sup>13</sup> I can then write the log of  $C_{it}^J$  as a simple log-linear function of several other observables

$$c_{it}^J = \beta_0 + \beta_1 p_{it} + \beta_2 FDI_{it} + \gamma_i + \alpha_t + \varepsilon_{it} \quad (1)$$

where  $c_{it}^J$  is the log of the number of citations made by the U.S. patent applications of Japanese firm  $i$  in year  $t$  to indigenous U.S. patents,  $p$  is the log of the count of U.S. patent applications of Japanese firm  $i$  in year  $t$ , FDI is one of a number of alternative measures of the FDI stock of firm  $i$  in year  $t$ , the  $\alpha_t$ ’s are time dummies, and  $\gamma_i$  is a “firm effect.” We would expect patent citations to rise as the cumulated stock of “citable” U.S. inventions increases, but the change in this stock will be absorbed into the time dummies. Japanese firms are likely to differ in the extent to which they work in regions of the technology space that are “densely populated” with prior U.S. inventions, and this could affect the propensity of Japanese firms to cite U.S. prior art. However, much of the difference in the technological specialization of Japanese firms is likely to be absorbed by the firm fixed effects, as are differences in the research productivity of firms.

The focus of interest will be on the coefficient  $\beta_2$ . Do firms that increase their levels of FDI in the United States experience an increased tendency to cite U.S. patents? The reason why one might expect a positive, significant coefficient is straightforward. To monitor and understand other firms’ R&D can be a difficult task – particularly when the other firms’ R&D activities are located on the opposite side of the Pacific Ocean. It may be facilitated enormously by the geographical proximity attained through FDI, through which the cost of accessing foreign firms’ knowledge assets is reduced.

However, there are also both theoretical and empirical reasons for thinking the spillover-enhancing effects of FDI differ depending on its type. Japanese firms that set up wholly-owned “greenfield” facilities in the U.S. may be doing to exploit substantial technological advantages that they

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<sup>13</sup> Inference will be based on citations to and from the U.S. patents of Japanese firms. For a discussion of why this is appropriate, please see the Data Appendix. Note that the U.S. Patent and Trademark Office only makes available data on patent applications that are eventually *granted*. In this paper, patents are dated by year of application rather than year of grant, because it takes on average two years – sometimes much longer – for the patent office to grant a patent.

hold over incumbent domestic firms.<sup>14</sup> For these firms, there may be little expectation of knowledge spillovers because of the relative backwardness of the local competition. On the other hand, empirical research has suggested that at least some Japanese acquisitions of U.S. firms are motivated by the desire to acquire American technology and “tap into” American technology networks.<sup>15</sup> In light of this, I will present results based on total FDI activity, as well as separate specifications measuring only greenfield FDI and acquisition, respectively. In addition, my data source is sufficiently detailed regarding the “business purpose” of the individual affiliates to allow me to identify affiliates whose purpose is R&D, product development, or the gathering of “market intelligence” for the parent firm. Japanese multinationals have been particularly aggressive about building up research centers in the United States over the last fifteen years, and many of these centers are set up with the express purpose of tracking and learning from U.S. technological innovations. I can thus estimate the impact of these affiliates, which are deliberately focused on “spillover augmentation,” separately from that of other affiliates that do not share this explicit mission.

If Japanese firms are changing the focus of their research activities in ways that bring them “closer” to U.S. firms in technology space, they may increase their citations of U.S. patents for reasons that have little to do with expanding FDI. To control for this, I borrowed the formulation of Jaffe (1986) to construct a time-varying measure of technological proximity between each Japanese firm in my data set and U.S. inventive activity.<sup>16</sup> The regression results reported in Tables 2-6 incorporate this measure, finding it to be statistically significant in some specifications.<sup>17</sup>

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<sup>14</sup> This view reflects the influence of the “internalization” theory of FDI. See Markusen (2001) and Helpman, Melitz, and Yeaple (2004) for recent theoretical work formalizing this notion. This view also reflects the influence of the recent literature on multinationals’ “mode of entry” into foreign markets. See Anderson and Gatignon (1986), Asiedu and Esfahani (2001), Gomes-Casseres (1989, 1996), and Javorcik and Saggi (2003).

<sup>15</sup> See Kogut and Chang (1991) and Blonigen (1997).

<sup>16</sup> Let the cumulated count of U.S. patents obtained by Japanese firm  $i$  at time  $t$  in various categories of technology be represented by the vector  $F_{it}$ , where  $F_{it} = (f_{1t}, \dots, f_{kt})$ . Each of the  $k$  elements of  $F$  measures the firm's cumulative patenting in the  $k$ th technological area as of time  $t$ . I aggregate the patent

For Americans, the question of greater interest may be not what the Japanese firms have learned through their investments, but what indigenous American inventors have gained from a greater Japanese presence in the United States. I can use a variant of the approach developed in the previous paragraphs to examine this. I begin by defining a new dependent variable,  $C_{it}^A$ , as the number of citations made to the cumulated stock of U.S. patents of Japanese firm  $i$  in year  $t$  by the universe of indigenous U.S.-invented patents applied for in year  $t$ . I can then consider the log of this count,  $c_{it}^A$ , to be a log-linear function of cited firm characteristics:

$$c_{it}^A = \beta_0 + \beta_1 p_{it} + \beta_2 FDI_{it} + \beta_3 Age_{it} + \gamma_i + \alpha_t + \varepsilon_{it} \quad (2)$$

where the variables have the same definitions as in (1), except for  $p$ . Here  $p$  stands, not for the number of patents applied for by Japanese firm  $i$  in year  $t$ , but rather the cumulative *stock* of patents held by Japanese firm  $i$  as of year  $t$ . This is because the number of citations a Japanese firm receives in a given year is likely to be a function of its cumulative *stock* of U.S. patents rather than the number of applications taken out in a particular year. Received citations will tend to increase with the number of potentially citing indigenous U.S. patents generated in year  $t$ , but this will be absorbed into the time dummies. I have also added a variable, *Age*, which is described below.

In their detailed studies of patent citations, Adam Jaffe and his co-authors have found that it takes time for the knowledge contained in patents to diffuse, such that patent citations initially increase over

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classes in the U.S. PTO classification system into fifty patent clusters, and calculate these vectors for the firms in my data set, year by year. In the same way, I can also compute a vector of location in technology space for the aggregate of all U.S. inventors, treating them as though they belonged to a single giant enterprise, and denote that  $F_{US_t}$ . This suggests that technological proximity could be measured as:

$$PROX_{it} = \frac{F_{it} F_{US_t}'}{[(F_{it} F_{it}')(F_{US_t} F_{US_t}')]^{1/2}}$$

<sup>17</sup> I also included a firm-level measure of real R&D spending in all regressions. Because R&D spending is highly correlated with measures of contemporaneous patenting, inclusion of this variable had little impact on the regression coefficients of interest. The coefficients on the R&D term are omitted to conserve space.

time. As time passes, the knowledge contained within patents becomes obsolete, so that patent citations have a tendency to *decrease* over longer lengths of time. Econometric work suggests that the frequency of citation for a given patent peaks on average 4-6 years after the granting of the patent. Since I want to control for differences in the “citedness” of different Japanese firms that are driven by differences in the age distribution of their patent stocks rather than FDI, I include for each Japanese firm in each year for which I have sufficient data the fraction of total U.S. patents that are at this peak “citing age”; this variable is denoted *Age*. This additional control is not needed in specification (1), because in that specification I am looking at citations made by a “new” cohort of patents generated by a Japanese firm at a point in time to a pre-existing stock of potentially cited American inventions.

Again, my interest will focus on  $\beta_2$ . Do U.S. inventors’ citations to the patents of a Japanese firm increase as the FDI presence of that firm increases? A positive, significant  $\beta_2$  would indicate this. As in earlier specifications, I measure FDI in four different ways: total cumulative counts of affiliates, cumulative counts of acquired affiliates, cumulative counts of R&D/product development facilities, and cumulative counts of greenfield affiliates. Specifications (1) and (2) are analogous, but not the same, and the estimates obtained from these specifications are not directly comparable. Because (2) measures spillovers from investing Japanese firms to indigenous American inventors, the relative impact of different kinds of FDI on measured spillover flows may be quite different. As with equation (1), one could extend equation (2) by including additional controls for firm real R&D spending and time-varying “technological proximity” vis-à-vis U.S. inventors, and I have done so in the results reported in this paper.

As a statistical matter, when one attempts to estimate (1) or (2), one finds there are a large number of observations for which the dependent variable is 0, and hence, the log of the dependent variable is undefined. I deal with this issue by using an econometric model especially designed for count data, in which 0 is a natural outcome -- the fixed effects negative binomial model developed by Hausman, Hall, and Griliches (1984).

### **III. Empirical Results: The Impact of FDI on International Knowledge Spillovers**

Data on FDI were taken from the *Kaigai Shinshutsu Kigyō Souran (Firm Overseas Investment)*, 1997 and 1999 editions, both published by *Toyō Keizai (Oriental Economist)*. Patent data were obtained from the U.S. Patent and Trademark Office and the NBER Patent Citation database, which is described in

Hall et al. (2000). Data on R&D spending were collected from various issues of the *Kaisha Shiki Ho (Japan Company Handbook)* series, published by *Toyoku Keizai (Oriental Economist)* and from various issues of the *Nikkei Kaisha Jouhou (Japan Company Information)* Series, published by the *Nihon Keizai Shimposha (Japanese Economy Publishing)*. Further details on data sources and construction are provided in the Data Appendix. Some sample statistics are provided in Table 1. Regressions are based on an unbalanced panel data set for 189 Japanese firms for the years 1980-1997. Note that data on FDI consist of *counts* of affiliates acquired or established in the U.S. Unfortunately, the nature of the data prevent me from weighting these counts by measures of the size of the relevant affiliates.<sup>18</sup> This will inevitably introduce error into the measurement of an individual firm's FDI presence in the U.S., potentially leading to a downward bias in estimates of the impact of FDI on knowledge spillovers.

#### *The Impact of FDI on Knowledge Spillovers to Investing Firms*

Results for citations *by* the patents of Japanese firms *to* the stock of “indigenous” U.S. patents are given in Table 2. These can be viewed as indicators of knowledge spillovers *to* Japanese firms *from* U.S. inventors. The designation of columns as (1), (2), (3), and (4) refers to the use of four alternative measures of FDI. Column (1) counts the cumulative sum of total affiliates, regardless of the means of establishment or the purpose of the affiliate. Column (2) counts only the cumulative sum of affiliates obtained through total or partial acquisition of pre-existing U.S. firms. Column (3) counts only the cumulative sum of affiliates whose “statement of business purpose” in the FDI database explicitly identifies it as an overseas R&D facility. Column (4) counts only “greenfield” affiliates whose business purpose is unrelated to R&D. In all cases, the measures of FDI are lagged by two periods. As the table indicates, the measured impact of FDI is positive and statistically significant for total counts and for counts of R&D facilities. The impact of acquisitions is statistically indistinguishable from zero, as is the impact of “greenfield” affiliates with no connection to R&D. This pattern of results suggests that the positive results for total counts may be driven by R&D facilities.

The coefficient on the FDI term has a “semi-elasticity” interpretation. For example, the coefficient on R&D affiliates provided in the third column suggests that setting up an additional R&D lab in the U.S. leads to a roughly 2% increase in annual flows of spillovers from U.S. inventors. While this

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<sup>18</sup> For a discussion of these measurement issues, see the Data Appendix.

would seem to be a rather modest effect, one has to keep in mind that some firms in my database had built up a rather extensive network of R&D and product engineering facilities in the U.S. by the end of my sample period. One firm had as many as 18 such facilities by the end of my sample period. Multiplying the estimated marginal effect of an increase in R&D affiliates by the magnitude of the increase in such affiliates that I actually observe for some firms in my sample implies cumulative effects on annual spillover flows that are quite large.

The limited impact of acquisition seems to be inconsistent with the work of Blonigen (1997), which suggested that Japanese FDI was motivated by the desire to acquire firm-specific assets. Conversations with U.S.-based managers of Japanese affiliates and a careful review of the data on individual acquisitions suggest some possible explanations for this apparent inconsistency. First, the number of recorded acquisitions by the manufacturing firms in my data set is small relative to the number of total subsidiaries, and this may lower the estimated impact of acquisition. Second, interviews indicate that the Japanese acquirers often found – to their frustration – that many of the key American individuals in whom these knowledge assets were quite literally “embodied,” would leave the firm shortly after acquisition. Both the direct knowledge and the entrée into local technological networks through personal connections that the Japanese acquirers hoped to obtain were not difficult to purchase, but extremely hard to retain over time. Third, a review of the identities of acquired firms suggests that Japanese acquirers were often more interested in obtaining a brand name or access to distribution channels than technology *per se*.

There is a clear and obvious relationship between the number of citations made by a firm’s cohort of patents to prior U.S. invention and the number of patents in that cohort. The coefficient on the log of the patent count is statistically indistinguishable from unity. The coefficient on the technological proximity term is of the expected sign, but it is not statistically significant at conventional levels.

Table 3 extends the results in Table 2 by exploring alternative lag structures for measures of R&D affiliates. As can be readily seen from the table, the estimated effects do not vary much for different lags. The estimated impact is slightly higher for the two-period and three-period lagged measures than for the contemporaneous or one-period lagged measures, but these differences are small relative to the magnitudes of the standard errors. While the robustness is reassuring, this also reflects the fact that the alternative lags are highly multicollinear.

### *The Impact of FDI on Spillovers **from** Investing Firms*

Having presented some evidence on the impact of Japanese FDI on knowledge spillovers from the U.S. to Japan, I now examine its impact on knowledge spillovers in the other direction. Table 4 measures spillovers *from* Japanese firms to indigenous American inventors. Following specification (2), I use as controls the evolving cumulated sum of U.S. patents (i.e., the patent stock) held by these investing Japanese firms and the changing age distribution of their U.S. patent stocks. I also include a time-varying measure of technological proximity vis-à-vis U.S. inventive activity and a measure of firm R&D spending as additional controls. To facilitate a comparison with Table 2, I use two-period lagged measures of FDI stocks in the regressions reported here.<sup>19</sup> Column (1) shows that (total) FDI has a positive and statistically significant effect on spillovers to American inventors. In column (2), however, the estimated coefficients suggest that the impact of acquisition FDI is statistically indistinguishable from zero. In column (3), the impact of U.S. R&D affiliates is positive and significant at conventional levels, and the estimated coefficient appears only slightly smaller in magnitude than that estimated in the “spillovers to” regressions.<sup>20</sup>

One might think that spillovers from investing Japanese firms to American inventors would be strongest where the Japanese firm possessed a technological advantage vis-à-vis its American competitors. In that context, the establishment of greenfield production facilities and distribution centers incorporating the parent firms’ technology and management practices might be expected to have the strongest impact on spillover flows to local firms. Evidence supporting this view is provided by the results of column (4), in

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<sup>19</sup> The fixed effects negative binomial estimation routine in STATA automatically drops firms for whom the dependent variable is zero in all periods. Five of my 189 firms, which have low levels of U.S. patenting, are never cited in any year by indigenous U.S. inventors. As a consequence, inference in the “spillovers from” regressions of Tables 4, 5, and 6 are based on a cross-section of 184 firms.

<sup>20</sup> The numbers of observations in the columns of Tables 2 and 4 differ slightly, because the negative binomial fixed effects estimator automatically disregards firms which register zero citations in all periods. Because the dependent variable differs in the “spillovers to” and “spillovers from” specifications, the number of dropped observations also varies. However, restricting these specifications to a common subset of observations yielded results that are qualitatively similar to those shown in the paper.

which I use a measure of greenfield production and distribution centers. I note that the measured coefficient on this FDI term is considerably larger than on the “total count” term employed in column (1), suggesting that leakage of technology from greenfield establishments is contributing significantly to the results shown in column (1).<sup>21</sup>

As in earlier specifications, I include a full set of time dummies, although the coefficients are not reported to conserve space. The other control variables generally have the expected sign and are statistically significant at conventional levels.<sup>22</sup>

If firms with more valuable technology tend to be the firms that most aggressively invest in greenfield affiliates, then one might worry that the pattern of results described above is simply reflecting the fact that firms with more valuable technology tend to receive more citations to their U.S. patents, rather than providing evidence on the relative importance of greenfield establishments as a channel of knowledge spillover to U.S. firms.<sup>23</sup> Fortunately, the panel structure of the data and the employment practices of Japanese firms during my sample period allow me to conduct a limited test of this alternative interpretation. I can re-estimate equation (2) over subperiods of my data set. Statistical inference would be based on changes within firms over that subperiod. The quality of technology possessed by the firm prior to the onset of that subperiod could be thought of as predetermined. Given the “lifetime employment” system that governed corporate labor market practices in Japan, the evolution of unmeasured “research quality”, particularly when one controls for the level of R&D effort, is plausibly slow enough that it changes little over periods on the order of five to eight years in length. Even in subperiods of that limited length, re-

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<sup>21</sup> When measures of greenfield affiliates and R&D affiliates are both used in the same specification, the coefficient on the former is more than twice as large as that of the latter, and hypothesis of equality can be rejected at the 10% level (p-value of .07).

<sup>22</sup> The technological proximity measure is consistently statistically significant in the “spillovers from” regressions. This difference with the “spillovers to” regressions may exist because the measure of patent stocks used here seems to absorb less of the “within firm” variance in the dependent variable in these regressions than the measure of contemporaneous patent counts absorbed in the “spillovers to” regressions.

<sup>23</sup> I thank an anonymous referee for raising this point.

estimation of equation (2) generated results qualitatively similar to those shown in Table 4. These results strengthen my initial interpretation of the greenfield FDI term.

Table 5 explores the use of different lags for the “greenfield” FDI term. As in Table 3, I find that the estimated impact does not vary much. The impact increases slightly for one-period lags relative to the others, but this difference is not large relative to the magnitudes of the standard errors. According to these regression results, the estimated marginal impact of an additional U.S. affiliate on spillover flows is approximately 2-3%. Again, this appears to be a modest effect, but the cumulative impact of a large increase in a firm’s U.S. “FDI presence” could be substantial. Some sample firms establish a significant number of U.S. affiliates over the course of the sample period. Multiplying this level of increase in a firm’s FDI stock by my estimated marginal effects implies a potentially large increase in knowledge spillover flows from these firms.

#### **IV. Extending the Empirical Analysis – FDI and Interfirm Technology Alliances**

In addition to aggressive FDI in the U.S., many Japanese firms in my sample have also exported substantial quantities of goods to the U.S. market and engaged in numerous technology licensing relationships and even cooperative R&D alliances with U.S. firms. It would obviously be of interest to measure the impact of FDI on international flows of knowledge spillovers, controlling for these alternative categories of international contact between Japanese and U.S. firms. Unfortunately, there is little publicly available data on firm’s exports to the U.S. At this point, I am unable to control simultaneously for the effects of trade.

However, much more extensive data are available for the firms in my sample on their technological cooperation, broadly defined, with U.S. firms. John Hagedoorn and his co-researchers at the University of Maastricht have constructed a comprehensive database of international technological cooperative activity which is based on publicly announced R&D alliances, cooperative product development efforts, and major technology licensing and cross-licensing initiatives, known as the Cooperative Agreements and Technology Indicators (CATI) database.<sup>24</sup> There are obvious problems with data based on contemporary press accounts, but this database is the most comprehensive publicly available data source on international technology collaboration. Using this CATI database, I have constructed, for

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<sup>24</sup> See the description of this data base in Gomes-Casseres, Jaffe, and Hagedoorn (2003).

each Japanese firm, a cumulative count of technology alliances with U.S. firms and institutions in force in that year.

Limitations in the CATI database prevent me from weighting these alliances by the amount of money invested in them. Nevertheless, these measures provide a firm-specific, time-varying measure of the intensity of a Japanese firms' collaborative R&D activity with U.S. firms and other U.S.-based research organizations. The existing literature on research alliances strongly suggests that formal R&D alliances between firms increase the level of cross-citation between participants.<sup>25</sup> Given that FDI and collaborative R&D activity are likely to be highly correlated, controlling for contemporaneous R&D collaboration would be an important robustness check on the impact of FDI on international knowledge spillovers.

Table 6 presents results of regressions of equations (1) and (2) with this alliance measure incorporated in a manner similar to that of the counts of foreign affiliates. Column (1) presents a version of equation (1) with only technology alliances, while column (2) includes measures of both technology alliances and counts of foreign (R&D) affiliates. Likewise, column (3) presents a version of equation (2), measuring spillovers to indigenous American inventors, while incorporating a measure of technology alliances. Column (4) re-runs this specification, using counts of both greenfield affiliates and technology alliances. The coefficients on the technology alliance and FDI terms have a semi-elasticity interpretation – they yield the percentage increase in annual spillover flows that result from an additional affiliate or alliance.

As can be clearly seen from column (2), R&D affiliates continue to have a positive, statistically significant impact on international knowledge spillovers *to* investing Japanese firms. The coefficient estimate on the alliance term – .001 – appears modest, but some firms in the sample maintain several dozen alliances at a given point in time. Similar results are shown in column (4) for spillovers *from* investing Japanese firms. The measured impact of “greenfield” FDI on knowledge spillovers to American inventors remains positive and statistically significant, even with the inclusion of the alliance counts.

## V. Conclusions

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<sup>25</sup> On this point, see, among other studies, Gomes-Casseres, Jaffe, and Hagedoorn (2003) and Mowery, Oxley, and Silverman (1998). For other studies of the impact of technology alliances on firm performance, see Stuart (2000) and Branstetter and Sakakibara (2002).

In this paper, I have used patent citations data to measure the importance of foreign direct investment in mediating flows of knowledge spillovers across national borders. I find evidence that FDI is a channel of knowledge spillovers, both *from* investing firms *to* indigenous firms and *from* indigenous firms *to* investing firms. Strategy experts have long asserted that investing abroad can be a useful way of tapping into foreign technology networks. My study upholds this belief with quantitative data, emphasizing the potential importance of multinational corporations as channels of knowledge spillovers between advanced economies.

In addition to establishing the basic result that foreign subsidiaries can serve as channels of knowledge spillovers, I find that the direction and degree of spillover flow is related to the characteristics of Japanese firms' U.S. subsidiaries in plausible ways. Knowledge spillovers received *by* the investing Japanese firms tend to be strongest via R&D and product development facilities. Given that these facilities are often explicitly designed to augment the ability of the investing Japanese firms to track and learn from research developments in the U.S., these results seem reasonable. On the other hand, spillovers from investing Japanese firms to indigenous American investors appear to flow most strongly through greenfield affiliates in which Japanese firms, often possessing a productivity advantage over American incumbents, are deploying superior technology and or managerial practices. These results are robust to the inclusion of a measure of technological alliances between U.S. and Japanese firms – a potential channel of international knowledge spillovers that much of the received literature in international economics has largely ignored.

The framework presented in this paper could be extended to analyze the impact of Japanese *exports* to the United States on the ability of the exporting firms to “learn from” U.S. technological developments (the focus of the “learning by exporting” literature). In a similar fashion, it could be extended to measure the impact of Japanese exports to the United States (that is, *imports* of Japanese goods by American inventors) on the propensity of *U.S.* innovators to cite Japanese inventions. Finally, the framework used in this paper could potentially serve as the basis for a more complete examination of the R&D-intensive multinational firm that links information on knowledge spillovers derived from patent citations to other “innovative output” measures. Such investigation is the focus of current research.

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**Table 1A Sample Statistics for Japanese Firms**

Variable	Mean	St. Dev.	Min	Max	Observations
Patents	62.93	173.19	0	2,006	2,485
R&D	21,917.03	53,111.07	46	546,000	2,485
Citations to U.S.- invented patents	134.77	408.24	0	4,465	2,485
Citations by U.S.- invented patents	124.04	455.69	0	6,895	2,485
U.S. affiliates	2.49	3.66	0	24	2,485
R&D affiliates	.497	1.39	0	18	2,485
Acquired affiliates	.314	.673	0	5	2,485
Greenfield affiliates	1.69	2.55	0	19	2,485

Units of R&D figures are millions of Japanese yen.

**Table 1B Firms with one or more affiliates in 1990**

Total affiliates	147
R&D affiliates	50
Acquired affiliates	53
Greenfield affiliates	120

**Table 1C Distribution of Firm-Year Observations Across Major Industry Groups**

Electronics	33%
Chemicals and Pharmaceuticals	26%
Transportation Equipment	14%
General Machinery	13%
Other Industries	14%

**Table 2 Spillovers to Japanese Firms**

	(1) Total	(2) Acquisition	(3) R&D	(4) Greenfield
<b>U.S. FDI (total) lagged 2 periods</b>	<b>.007 (.002)</b>			
<b>U.S. FDI (acquisition) lagged 2 periods</b>		<b>-.007 (.010)</b>		
<b>U.S. FDI (R&amp;D) lagged 2 periods</b>			<b>.016 (.003)</b>	
<b>U.S. FDI (greenfield) lagged 2 periods</b>				<b>.003 (.003)</b>
<b>Proximity</b>	.188 (.116)	.192 (.117)	.166 (.116)	.197 (.116)
<b>log U.S. patents</b>	.996 (.012)	1.01 (.012)	.989 (.012)	1.00 (.011)
<b>Log Likelihood</b>	-7,234.10	-7,242.17	-7,227.64	-7,242.03
<b>Firms</b>	189	189	189	189
<b>Observations</b>	2,389	2,389	2,389	2,389

All columns present results of fixed effects negative binomial regressions. Standard errors are given in parentheses.

- (1) Indicates FDI measured as cumulative counts of all U.S. subsidiaries.
  - (2) Indicates FDI measured as cumulative counts of acquired U.S. subsidiaries.
  - (3) Indicates FDI measured as cumulative counts of U.S. R&D/product development facilities.
  - (4) Indicates FDI measured as cumulative counts of greenfield non-R&D affiliates.
- All specifications include a full set of year dummies and the log of firm real R&D spending.

**Table 3 Spillovers to Japanese Firms**

	(1)	(2)	(3)	(4)
<b>U.S. FDI (R&amp;D) (Contemporaneous)</b>	<b>.014 (.003)</b>			
<b>1-pd. Lagged FDI (R&amp;D)</b>		<b>.014 (.003)</b>		
<b>2-pd. Lagged FDI (R&amp;D)</b>			<b>.016 (.003)</b>	
<b>3-pd Lagged FDI (R&amp;D)</b>				<b>.016 (.003)</b>
<b>Proximity</b>	.176 (.110)	.179 (.110)	.166 (.116)	.170 (.127)
<b>log U.S. patents</b>	.994 (.011)	.993 (.011)	.989 (.012)	.990 (.012)
<b>Log Likelihood</b>	-7,566.25	-7,544.57	-7,227.64	-6,897.76
<b>Firms</b>	189	189	189	189
<b>Observations</b>	2,485	2,478	2,389	2,296

Columns (1)-(4) present the results of negative binomial fixed effects regressions with various lags of counts of R&D affiliates. Standard errors are given in parentheses. The use of lagged terms reduces the number of observations in columns (2)-(4). All specifications include a full set of year dummies and the log of firm real R&D spending.

**Table 4 Spillovers from Japanese Firms**

	(1) Total	(2) Acquisition	(3) R&D	(4) Greenfield
<b>U.S. FDI (total)</b>	<b>.014</b> <b>(.002)</b>			
<b>U.S. FDI (acquisition)</b>		<b>.008</b> <b>(.012)</b>		
<b>U.S. FDI (R&amp;D)</b>			<b>.015</b> <b>(.004)</b>	
<b>U.S. FDI (greenfield)</b>				<b>.024</b> <b>(.004)</b>
<b>Proximity</b>	.609 (.151)	.624 (.152)	.587 (.152)	.646 (.150)
<b>log U.S. patents</b>	.712 (.023)	.729 (.023)	.717 (.023)	.719 (.023)
<b>Age</b>	.790 (.073)	.770 (.074)	.799 (.074)	.757 (.073)
<b>Log Likelihood</b>	-6,913.94	-6,932.15	-6,924.78	-6,915.90
<b>Firms</b>	184	184	184	184
<b>Observations</b>	2,362	2,362	2,362	2,362

All columns present results of fixed effects negative binomial regressions. Standard errors are given in parentheses.

(1) Indicates FDI measured as cumulative counts of all U.S. subsidiaries.

(2) Indicates FDI measured as cumulative counts of acquired U.S. subsidiaries.

(3) Indicates FDI measured as cumulative counts of U.S. R&D/product development facilities.

(4) Indicates FDI measured as cumulative counts of U.S. greenfield non-R&D affiliates.

All specifications include a full set of year dummies and the log of firm real R&D spending. Five firms in the sample are automatically dropped because they receive zero citations from indigenous American inventors in all years. This reduces the cross-section from 189 firms to 184 firms.

**Table 5 Spillovers from Japanese Firms**

	(1)	(2)	(3)	(4)
<b>U.S. FDI (Contemporaneous)</b>	<b>.022</b> <b>(.004)</b>			
<b>1-pd. Lagged FDI</b>		<b>.026</b> <b>(.004)</b>		
<b>2-pd. Lagged FDI</b>			<b>.024</b> <b>(.004)</b>	
<b>3-pd. Lagged FDI</b>				<b>.022</b> <b>(.004)</b>
<b>Proximity</b>	.566 (.143)	.576 (.143)	.646 (.150)	.705 (.159)
<b>log U.S. patents</b>	.725 (.023)	.728 (.023)	.719 (.023)	.712 (.023)
<b>Age</b>	.760 (.072)	.760 (.072)	.757 (.073)	.734 (.074)
<b>Log Likelihood</b>	-7,215.35	-7,189.69	-6,915.90	-6,608.47
<b>Firms</b>	184	184	184	184
<b>Observations</b>	2,458	2,451	2,362	2,269

Columns (1)-(4) present the results of negative binomial fixed effects regressions with various lags of counts of greenfield affiliates. Standard errors are given in parentheses. The use of lagged terms reduces the number of observations in column (2)-(4). All specifications include a full set of year dummies and the log of firm real R&D spending.

**Table 6 Impact of Technology Alliances on Knowledge Spillovers**

	(1)	(2)	(3)	(4)
	Spillovers to Japanese firms		Spillovers from Japanese firms	
<b>Technology alliances (counts)</b>	<b>.002</b> <b>(.0005)</b>	<b>.001</b> <b>(.0006)</b>	<b>.005</b> <b>(.0006)</b>	<b>.004</b> <b>(.0007)</b>
<b>U.S. FDI (R&amp;D affiliates)</b>		<b>.011</b> <b>(.003)</b>		
<b>U.S. FDI (greenfield affiliates)</b>				<b>.015</b> <b>(.005)</b>
<b>Proximity</b>	.332 (.119)	.250 (.121)	.713 (.149)	.716 (.150)
<b>log U.S. patents (annual flow)</b>	.994 (.012)	.990 (.012)		
<b>log U.S. patents (stock)</b>			.719 (.023)	.715 (.023)
<b>Age</b>			.790 (.073)	.778 (.073)
<b>Log Likelihood</b>	-7,233.01	-7,227.71	-6,908.78	-6,903.70
<b>Firms</b>	189	189	184	184
<b>Observations</b>	2,389	2,389	2,362	2,362

All columns report results from a fixed effects negative binomial specification. Standard errors are given in parentheses. Columns (1) and (2) incorporate measures of technology alliances into versions of specification (5), measuring spillovers to investing Japanese firms. Columns (3) and (4) incorporate measures of technology alliances into versions of specification (8), measuring spillovers from investing Japanese firms to indigenous firms. All specifications include a full set of year dummies and the log of firm real R&D spending.

## Data Appendix

In order to keep the text of the paper reasonably short, I have omitted a number of details about data sources, data construction, and the empirical methodology. This Data Appendix describes the basic data sources in greater detail. It also reviews some of the key learnings from interviews conducted by the author with managers of Japanese firms investing in the United States.

### *Data Sources and Measurement Issues*

The primary source of data on the U.S. FDI of Japanese firms is *Kaigai Shinshutsu Kigyō Souran (Firm Overseas Investment)*, published in Japanese by the *Toyou Keizai (Oriental Economist)* publishing company of Japan. This source provides detailed data on FDI activity at the firm level. Japanese FDI in the U.S. (as opposed to FDI from other significant source countries) is of particular interest, because it changed so dramatically over the course of the 1980s and 1990s. A large number of Japanese multinationals shifted from a position of very limited direct investment (or no direct investment) in the U.S. at the beginning of my sample period to a position of “substantial” direct investment by the end. This large change may help identify the parameters of interest. The unit of analysis in the *Kaigai Shinshutsu Kigyō Souran* data source is that of the enterprise or business. In principle, one might want to weight counts of acquired or established enterprises by the size of these enterprises. In practice that is difficult, as the data on employment or sales of U.S. affiliates of Japanese firms are not recorded in this source with consistency.

Data on parent firms’ industry affiliation were taken from the Japan Development Bank Corporate Finance database. Data on the R&D spending of Japanese firms were taken primarily from survey data published (in Japanese) in the *Kaisha Shiki Ho (Japan Company Handbook)* and *Nikkei Kaisha Jouhou (Japan Company Information)* quarterly series of reports on Japanese publicly traded firms. Data on the U.S. patenting of Japanese firms were taken from the NBER Patent Citation Database, described in Hall, Jaffe, and Trajtenberg (2001), which, in turn, draws upon the electronic records of the U.S. Patent and Trademark Office. The years of my sample period are 1980 through 1997, although only a handful of Japanese firms report R&D spending in 1980.

This study uses data on the U.S. patents of 189 Japanese firms and the universe of “American” inventors. All U.S. patents assigned to these Japanese firms or their foreign subsidiaries were considered to

be “Japanese,” even if the patented invention was created in the United States. The set of “indigenous” American patents was defined as all U.S. patents, not assigned to the Japanese firms in my sample or their subsidiaries, which list a U.S. address for the first inventor. “American” inventors working for non-U.S. multinationals are considered “American” for the purposes of this study.<sup>26</sup> Conversely, foreign inventors (that is, inventors with a non-U.S. address) working for U.S. firms are not counted as part of the body of “American” inventors. This is intentional, in that the purpose of this study is to examine the impact of the geographic proximity conferred by FDI *in the U.S.* on spillovers to and from inventive activity *physically located in that country*. It is also worth noting that the vast majority of R&D activity conducted by U.S. multinationals is undertaken within the boundaries of the United States.

For this study, there was really no alternative to the use of data on Japanese firms’ U.S. patents, as Japanese patent law does not require inventors to disclose citations to the prior art. Nevertheless, interviews with leading Japanese firm executives and empirical studies suggest that Japanese firms seek to patent all their valuable ideas in both the U.S. and Japan, so that trends in their U.S. patents should be reflective of their total innovative activity. Note that Japanese firms are by far the most important foreign users of the U.S. patent system, accounting for roughly one quarter of all patents granted by the U.S. during the latter 1980s and early 1990s.

#### *Qualitative Evidence from Practitioner Interviews*

In order to obtain a “practitioner’s perspective” on the extent to which FDI functions as a channel of knowledge spillovers, I conducted a series of interviews with Japanese industry observers, government officials at the Ministry of Economy, Trade and Industry (the government agency charged with overseeing the foreign direct investment activities of Japanese firms, formerly known as MITI), Japanese managers of high-tech corporations, and Japanese managers of affiliates based in the United States. These interviews were conducted in the fall of 2000.

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<sup>26</sup> To be more precise, “American” inventors who produce patents assigned to the investing Japanese parent company are always considered to be “Japanese.” Americans working for “native” enterprises that are subsequently acquired by Japanese firms are effectively removed from the analysis undertaken in this paper, because all of the patents produced by these firms are excluded from the regressions reported herein.

All interviewees agreed with the view that foreign direct investment in the United States facilitates knowledge spillovers, as I have defined that term in this paper. It was also clear from discussions with the managers of Japanese research facilities in the U.S. that a major priority of at least some of these facilities is “tracking” U.S. technological developments in universities and among the leading firms.<sup>27</sup> However, the interviewees also suggested that useful technology is sometimes absorbed by U.S. affiliates that are not “pure” research organizations. They also agreed with the view that Japanese technology “leaks out” through their U.S. subsidiaries. In fact, this “leakage” is sometimes deliberately *fostered* by the Japanese firms. One example of this is attempts by Japanese firms to educate their local suppliers concerning Japanese technology and management practices.

Japanese firms make an effort to maintain a reasonably high degree of communication and coordination between their central R&D operations and their U.S. R&D facilities. One manager of such a facility claimed to communicate on a *daily* basis with the parent company and to physically travel to Japan several times per year for conferences with central R&D managers. The same manager claimed that his firm sends large numbers of engineers from the Japanese parent company to U.S. facilities each year on short term visits, essentially to promote knowledge spillovers. As mentioned in the text, conversations with managers of Japanese firms’ U.S. R&D facilities indicated a strong connection between these facilities and formal research alliances between the parent and U.S. firms. The location of U.S. R&D facilities was often chosen because of the proximity of potential American research partners. Engineers dispatched to U.S. R&D facilities often play an important role in managing interfirm research collaboration with American firms and universities.

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<sup>27</sup> A particularly effective method of “tapping into” U.S. technological developments is to hire engineers, technology managers, and research scientists away from leading American firms and universities. This is a high priority for many Japanese research facilities, but also a continuing challenge. Many traditional Japanese labor market practices, such as lifetime employment, seniority based wages, slow promotion tracks, and consensus-style decisionmaking, do not fit well with the more entrepreneurial culture of such U.S. technology centers as Silicon Valley.