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Foreign Direct Investment and R&D Spillovers
Is There a Connection?

Lee Branstetter

4.1 Introduction

The surge of Japanese foreign direct investment (FDI) after the 1985 Plaza Accords has been well documented and extensively studied. Direct investment by Japanese firms in the U.S. manufacturing sector was an important part of this total movement of capital abroad, as figure 4.1 indicates. While Japanese aggregate FDI statistics contain some well-known flaws, these figures nevertheless indicate that in 1989 some $33.9 billion of total FDI flowed into the United States from Japan, representing about 50 percent of total Japanese FDI.[1] Of this total inflow into the United States, approximately $24.3 billion consisted of direct investment outside of the manufacturing sector (much of it in finance and real estate), while the remaining $9.6 billion consisted of direct investment in manufacturing. While such high-profile nonmanufacturing acquisitions as Rockefeller Center, Pebble Beach, and Columbia Pictures received much media attention, it is worth pointing out that, in aggregate, Japanese firms' total manufacturing investments in the United States exceeded, in dollar terms, their

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1. See, e.g., Weinstein (1996) and Ramstetter (1996) on the flaws of statistics on FDI in Japan.

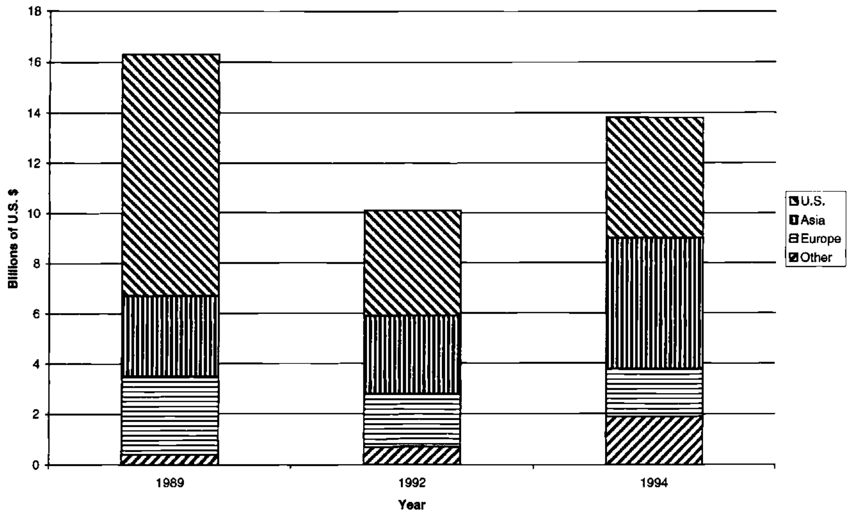

Fig. 4.1 Japanese manufacturing FDI
Source: Ministry of International Trade and Industry, *Tsusho Hakusho* (Tokyo, various issues).

direct investments in manufacturing in Asia until 1994. Both kinds of FDI raised concerns in the United States, where, prior to the 1980s, foreign-owned firms had played a relatively small role in the economy. Nevertheless, even at the height of Japanese investment in the United States, Japanese purchases of "trophy" real estate properties raised less concern than Japanese investments in U.S. manufacturing, particularly the acquisition of existing U.S. firms in industries where the United States was perceived to maintain a competitive advantage.

These concerns were partly motivated by the perception, correct or not, that U.S. investment in Japan was more difficult than Japanese investment in the United States. However, for many in and out of government who worried about the "competitiveness" of U.S. industries in the late 1980s, the real source of unease was the belief that by being more geographically proximate to the headquarters, manufacturing plants, and R&D facilities of their U.S. competitors (and, in some cases, owning these assets outright through acquisition) Japanese firms would be able to "tap into" U.S. sources of technological strength, further eroding U.S. competitive advantages in the few industries and industry segments where the United States was perceived to maintain such strength.[2]

While the subsequent revival of American high-tech manufacturing and

2. The anxious mood of the times was well captured in the title of one academic volume published in 1989 by the Society for Japanese Studies, *Japanese Investment in the United States: Should We Be Concerned?*

the well-publicized problems of Japanese companies have taken these issues off the policy agenda, it is still an open empirical question whether Japanese FDI increased the ability of Japanese firms to learn from the research activities and technological strengths of U.S. firms. The idea that tapping foreign sources of technological strength through FDI and acquisition could be a profitable corporate strategy has received strong support from one of the world's best-known corporate strategy experts, Michael Porter, in his best-selling 1990 book, *The Competitive Advantage of Nations.* Porter provides little in the way of quantitative empirical evidence to support his claim that foreign knowledge and expertise can be effectively "siphoned" through judicious FDI. However, he buttresses his plausible argument with some fascinating "case studies."[3]

This idea has also received both renewed interest and qualified support from the expanding theoretical and empirical economic literature on international R&D spillovers and the channels by which they are mediated. Since the theoretical work of Grossman and Helpman emphasized the potential importance of both intranational and international R&D spillovers in models of trade and growth, a number of researchers have attempted to both quantify the importance of international R&D spillovers and investigate the means by which they are mediated. Early work by Coe and Helpman (1995), using aggregate data for a set of advanced economies, claimed that R&D spillovers were mediated through trade and that the effects were quite strong. Eaton and Kortum (1996), examining the related concept of technology transfer, found suggestive evidence of significant knowledge flows across countries. More recent work by Keller (1998) at the aggregated industry level qualified both the importance of these spillovers and the extent to which they are actually mediated through trade. Branstetter (forthcoming), who examined international and intranational spillovers at the firm level in the United States and Japan, found striking evidence that R&D spillovers are primarily an intranational phenomenon. Despite its obvious potential importance as a means of mediating knowledge flows, comparatively little empirical analysis has been conducted on FDI and the role it may play as a channel of R&D spillovers.

This gap in the literature is mirrored by a similar gap in the now rather voluminous literature on the benefits of "outward-oriented" economic policies. Many scholars have asserted that exports are likely to have important effects on economic growth due to the "knowledge spillovers" indigenous firms receive when they export to advanced country markets.[4] Much of the dynamic growth in the East Asian region has been ascribed to the spillover benefits allegedly received by East Asian firms through

3. See the section of Porter (1990) entitled "Tapping Selective Advantages in Other Nations" (606–13).

4. The emphasis placed by this literature on exports differs from that of the literature described in the previous paragraph, which emphasizes the role of *imports* as a channel of technology spillovers.

exports.[5] In fact, several well-executed microeconometric studies have found essentially *no* link between productivity growth at the firm level and the percentage of firm output that is exported.[6] However, many of these papers have not introduced an explicit channel whereby exporting might lead to higher levels of knowledge spillover. This paper introduces such a channel and explicitly tests its significance.

Thus this paper attempts to fill the gap in the literature by investigating the extent to which the stocks of foreign investment of Japanese firms in the United States are correlated with increased capacity to obtain useful technological spillovers from the research activities of U.S.-based firms. I also examine the extent to which Japanese firms' levels of exports to the U.S. market are correlated with increased capacity to obtain such spillovers from U.S. firms. To that end, I use microlevel data on the technological activities of Japanese firms, their FDI activities in the United States, and their exports to the U.S. market. The paper presents estimates of the impact of FDI on the R&D spillovers that these Japanese firms receive from U.S. firms. I find that firms with large stocks of FDI do tend to obtain slightly greater benefits from research conducted in the United States. However, this effect, while quite robust, is also small in magnitude. On the other hand, I find a much stronger relationship (in terms of magnitude of the estimated coefficients) between knowledge spillovers and higher levels of exports to the U.S. market, though these effects are less robust. I conclude with a number of caveats concerning these results and some suggestions for further research.

4.2 Prior Literature

The Japanese surge in FDI after 1985 has attracted the attention of economists, and a large number of well-executed studies have appeared in the literature. Studies have tended to focus on three different sets of questions. The first is as follows: What determines when and where Japanese firms invest? Important contributions to the resolution of this question in the English-language literature include the work of Caves (1993) and Drake and Caves (1992) at the industry level and of Kyoji Fukao et al. (1994) and Belderbos and Sleuwaegen (1996) at the firm level. Eaton and Tamura (1996) presented an interesting study using Japanese and U.S. data at the aggregate level.[7]

The second set of questions addressed by the literature is this: What are the effects of Japanese firm FDI on the host country and host country

5. See, e.g., chap. 6 of the World Bank (1993) study *The East Asian Miracle,* particularly the section "How Manufactured Exports Increased Productivity."

6. These studies include Bernard and Jensen (1999), Clerides, Lach, and Tybout (1998), and Aw, Chen, and Roberts (1997).

7. There are, of course, many other interesting studies that I do not have time or space to review.

firms in the targeted industry? One can make the argument that inward FDI allows the transfer to the host country of firm-specific intangible assets, including the "knowledge capital" of the firm, that might not be available through arm's-length market transactions such as licensing or exports and imports of goods embodying firm-specific knowledge capital. It is further believed that the impact of this technology transfer may spread beyond the multinational subsidiary, diffusing to local indigenous producers. Tax concessions for multinationals and other policies designed to attract foreign investment seem to be predicated on this belief.[8] However, past empirical analyses of FDI at the firm level have generally failed to find any strong statistical relations at the micro level between FDI or tie-ups to foreign firms and productivity growth of indigenous firms at the firm or plant level.[9] Rather, the evidence suggests that the positive effect of the presence of FDI comes through its impact on domestic competition, raising the allocative efficiency of the host country industry by driving out less efficient producers.[10]

This paper focuses on a different question: What are the effects of Japanese firm FDI on the *honsha*—that is, the impact on the operations of the parent firm in Japan? Again, the most important contributions to this line of research have come from Japan, where there is widespread concern that Japanese firms are substituting foreign for domestic production, lowering the demand for domestic production workers. To get at this issue most directly, a number of papers have focused on the extent to which FDI substitutes for or, alternatively, complements exports from the parent firm. I do not have space to review all of the papers that deserve mention, but I will note a few that are most relevant to the research conducted in this paper.

One of the most provocative contributions is by Fukao and Toru (1995). These authors found strong substitution effects between domestic and foreign production labor. These findings are corroborated by Blonigen (1996), but not by Head and Ries (1997). As far as I know, no one has

8. E.g., China's regulatory regime for FDI heavily favors multinationals who bring in "advanced technology."

9. The papers to which I am referring here do not focus exclusively on FDI by Japanese firms. Some of the best known work along these lines are papers by Columbia University economist Ann Harrison and a group of coauthors that fail to find evidence at the firm level of technology spillovers from the local subsidiaries of multinationals to indigenous producers in either Morocco or Venezuela. See Haddad and Harrison (1993) and Aitken and Harrison (1999). On the other hand, the survey by Blomström and Kokko (1996) cited studies at the industry level that do suggest the existence of such spillover effects. Aitken, Hanson, and Harrison (1997) find evidence of indigenous firms learning about export opportunities from the local affiliates of multinational firms, but this can be distinguished from flows of technology, per se.

10. Chung, Mitchell, and Yeung (1996) studied the productivity impact of Japanese FDI in the North American auto component industry. They found that U.S. parts suppliers with links to Japanese assembly plants actually registered *lower* rates of productivity growth than unaffiliated parts suppliers in the 1980s. Their evidence suggests that Japanese FDI did have a positive effect on productivity in the American industry but that this effect was almost entirely due to the increased competition the Japanese plants brought to the U.S. market.

analyzed at the firm level the impact of FDI on the ability of parent firms to "learn from" R&D conducted abroad. However, previous papers in the literature on Japanese FDI provide some indirect evidence on the importance of technology acquisition as a motive for Japanese FDI. A number of empirical studies, including those of Kogut and Chang (1991, 1996), Yamawaki (1991), and Blonigen (1997) have all found that Japanese U.S. acquisitions, in particular, are motivated by the desire to access technology.[11]

Almeida (1996) undertook research that bears some similarity to the work conducted in this paper.[12] He examined the patterns of citations of patents produced by U.S.-based subsidiaries of foreign multinational firms in the semiconductor industry. Almeida found that the patents generated by these subsidiaries cite other local patents more intensively than does a control group of "domestic" patents. He also found that the patents generated by these subsidiaries are cited more intensively by other local firms than are the control group. However, this study said nothing about how the presence of a subsidiary affects the research operations *of the parent firm.* This is an important omission because, even in high-tech sectors, multinationals tend to conduct the overwhelming majority of their total R&D effort in the home country. The innovative activities of foreign subsidiaries are only a small part of total firm R&D effort. An additional shortcoming of Almeida's research is that it was based on an analysis of only 114 patents generated by the subsidiaries of only twenty-two firms in a single industry. To put these numbers in perspective, since the early 1980s Hitachi Seisakushou (Hitachi Ltd.) has received more than six times as many patent grants in the United States as that 114 patent sample *every single year.*

This paper, then, takes a first look at the impact of FDI on the parent firms' ability to benefit from R&D undertaken abroad. It complements this analysis with a similar investigation of the relationship between exports to the U.S. market and the ability to receive R&D spillovers. In order to conduct such a study, one first has to establish an empirical framework for measuring R&D spillovers. This framework, based on work by Jaffe (1986), is developed below.

4.3 Empirical Methodology

4.3.1 A Framework for Measuring Knowledge Spillovers

This section borrows heavily from Branstetter (forthcoming), which, in turn, builds on the methodologies suggested by Zvi Griliches (1979) and

11. Wesson (1998) also found evidence of the importance of this motivation for FDI in the United States.

12. I thank Mariko Sakakibara for bringing this paper to my attention.

first implemented by Adam Jaffe (1986). The typical firm conducts R&D in a number of technological fields simultaneously. Let firm i's R&D program be described by the vector F_i where

$$F_i = (f_1, \ldots, f_k) \tag{1}$$

and each of the k elements of F represents the firm's research resources and expertise in the kth technological area.[13] We can infer from the number of patents taken out in different technological areas what the distribution of R&D investment and technological expertise across different technical fields has been. In other words, by counting the number of patents held by a firm in a narrowly defined technological field, we can obtain a quantitative measure of the firm's level of technological expertise in that field.[14] Thus the F-vector provides us with a measure of the firm's location in technology space. Over time, of course, a firm can change its location by building technological expertise in new areas, but this takes time and the adjustment costs associated with this kind of change can be high. For this reason, I calculate for each firm in my sample a single location vector based on its patenting behavior over the entire sample period.

Griliches and Jaffe have reasoned that R&D spillovers between firms should be proportional to the similarity of their research programs. Given that firms working on the same technologies will tend to patent in the same technological areas, a measure of technological proximity can be constructed from the F-vectors defined in equation (1). The "distance" in technology space between two firms i and j can be approximated by T_{ij}, where T_{ij} is the uncentered correlation coefficient of the F-vectors of the two firms, or

$$T_{ij} = \frac{F_i F_j'}{[(F_i F_i')(F_j F_j')]^{1/2}}. \tag{2}$$

Other things being equal, firm i will receive more R&D spillovers from firm j if firm j is doing a substantial amount of R&D. Firm i will also receive more R&D spillovers if its research program is very similar to that of firm j. Thus the total potential pool of international R&D spillovers for a firm can be proxied by calculating the weighted sum of the R&D performed by all other foreign-based firms with the "similarity coefficients" for each pair of firms, T_{ij}, used as weights. The potential international, or

13. The k areas represent technological areas (based on the technology classification scheme of the U.S. patent office) rather than industry classifications. We do control for industry effects elsewhere, but here we aim to measure *technological proximity* rather than proximity in a "product market" sense.

14. Obviously, advances in some technological fields are more easily codified into and protected by patents than advances in others. However, the F-vector can still function as a reasonable measure of "relative" position in technology space as long as the "ease of codification" varies across fields in a common way across firms.

"foreign," spillover pool for the ith firm in the tth year is K_{fit}, where

$$(3) \qquad K_{fit} = \sum_{i \neq j} T_{ij} R_{jt} .$$

Here R_{jt} is the R&D spending of the jth firm (j not equal to i) in the tth year and T_{ij} is the similarity coefficient.[15] Similarly, the potential intranational, or "domestic," spillover pool is computed as

$$(4) \qquad K_{dit} = \sum_{i \neq j} T_{ij} R_{jt} ,$$

where, in this equation, R_{jt} is the R&D performed in the tth year by firms based in the *domestic* country, again weighted by the T_{ij}'s. Assume that innovation is a function of own R&D and external knowledge. Then the "innovation production function" for the ith firm in the tth year is

$$(5) \qquad N_{it} = R_{it}^{\beta} K_{dit}^{\gamma_1} K_{fit}^{\gamma_2} \Phi_{it} ,$$

where

$$(6) \qquad \Phi_{it} = e^{\sum_c \delta_c D_{ic}} e^{\varepsilon_{it}}$$

is a set of industry dummy variables and a multiplicative error term. Here the δ's can be thought of as exogenous differences in the "technological opportunity" of c different industries.

Taking the logs of both sides of equation (5) yields the following log-linear equation

$$(7) \qquad n_{it} = \beta r_{it} + \gamma_1 k_{dit} + \gamma_2 k_{fit} + \sum_c \delta_c D_{ic} + \varepsilon_{it} .$$

In equation (7), n_{it} is innovation, r_{it} is the firm's own R&D investment, k_{dit} is the domestic spillover pool, k_{fit} is the international spillover pool, the D's are dummy variables to control for differences in the propensity to generate new knowledge across industries (indicated by the subscript c), and ε is an error term. The γ coefficients measure the "innovative output elasticity" of the domestic and international spillover pools.[16]

Unfortunately, there are no direct measures of innovation. However, if

15. Note that T_{ij} is not indexed by time because it is constructed from the time-invariant F-vectors.

16. One might suppose that external R&D only enters into the knowledge production function with a long and variable lag. Unfortunately, due to the features of the data, the precise lag structure of external R&D is likely to be difficult to identify. However, it is worth noting that empirical research suggests that the time required for new innovation to "leak out" is quite short. Mansfield's celebrated 1985 paper found that 70 percent of new product innovations leak out within one year and only 17 percent take more than eighteen months. Caballero and Jaffe (1993) found that diffusion of new knowledge as measured by patent citations is about as rapid.

some fraction of new knowledge is patented, such that the number of new patents generated by the ith firm is an exponential function of its new knowledge, as given by

$$(8) \qquad P_{it} = e^{\sum_c \alpha_c D_{ic}} e^{\xi_i} N_{it},$$

then the production of new knowledge can be proxied by examining the generation of new patents.[17] We take the logs of both sides of equation (8), and substituting into equation (7), we get

$$(9) \qquad p_{it} = \beta r_{it} + \gamma_1 k_{dit} + \gamma_2 k_{fit} + \sum_c \delta_c D_{ic} + \mu_{it},$$

where p_{it} is the log of the number of new patents and the other variables are as before, except for the error term, which is defined below.[18] With this substitution, the interpretation of the coefficients on the D's has changed. They now represent industry-level differences in the propensity to patent, which are a function of both the technological opportunity in the cth industry, as in equation (6), *and* the usefulness of patents as a tool of appropriation in the cth industry. It is known that strong differences in both factors exist across industries.

Note, however, that because of this substitution, the interpretation of the γ's has also necessarily changed. We do not observe the "pure effects" of knowledge spillovers on firm innovation because we do not directly observe innovation. We instead observe the effects of knowledge spillovers on economic manifestations of the firm's innovation, its patents. If technological rivalry with other firms is intense enough and the scope of intellectual property rights conferred by patents is broad enough, firms may sometimes find themselves competing for a limited pool of available patents—a patent race. For this reason, the positive technological externality of other firms' R&D is potentially confounded with a *negative* effect of other firms' research *due to competition.*[19] Thus, if actual flows of knowl-

17. Note that this formulation allows for both industry and firm differences in the propensity to patent. This flexibility is important given the observed differences in patenting behavior across firms and industries.

18. One advantage of using patents as an indicator of innovative output is the demonstrated immediate, tight link between R&D and patent generation. Survey evidence from the United States and Germany indicates that the time lag from initial conception of an idea to the filing of a patent application is about nine months (Scherer 1984)! Careful econometric evidence also suggests that the link between patenting and R&D is largely contemporaneous. On the other hand, the link between R&D and changes in revenue (and revenue-based measures such as total factor productivity), which result from the successful introduction of new products, is subject to long, variable lags.

19. To make this explicit, we can decompose the γ's in the following fashion: $\gamma = (\partial n/\partial k)(k/n) - (\partial p/\partial k)(k/p)$. In other words, the γ's that we observe are the net result of two opposite effects—the "true" positive technological externality of external knowledge on firm i's innovation, $\partial n/\partial k$, and a negative "patent race effect," $\partial p/\partial k$, in which the ith firm's ability to patent new innovation is crowded out by the previous patenting of competitive firms. Adam Jaffe (1986) and others have also made this point.

edge are limited or weak and rivalry is strong, our estimates of the γ's may be negative even though the underlying knowledge externality is positive.[20] Unfortunately, it is not possible to disentangle these two effects in the data, though my empirical results suggest that both are present.[21]

In Branstetter (forthcoming), regressions along the lines of equation (9) were run for both U.S. and Japanese R&D-intensive firms. The somewhat surprising results of these regressions suggest that R&D spillovers are primarily an *intranational* phenomenon. Controlling for the presence of intranational R&D spillovers, I found little evidence of positive, significant international R&D spillovers. This result was robust to the use of data from either the United States or Japan and robust to changes in the functional form of the estimating equation. Similar results were obtained when an index of total factor productivity (levels) was used as the dependent variable. These results should be kept in mind in interpreting the empirical results presented in this paper. I find that in this paper, the impact of foreign spillovers tends to be "overwhelmed" by the impact of domestic knowledge spillovers when both terms are included in the regression. This is consistent with my own earlier results and with other recent evidence on the geographic localization of knowledge spillovers.[22]

However, these results should be interpreted as measuring the *average* "innovative output elasticities" of international and intranational R&D spillovers obtained by pooling data on both small and large corporations, some of which have substantial connections to markets and technological developments abroad through exports and FDI. Is it possible that the impact of international R&D spillovers is substantially higher for firms with a high level of exports to or FDI in the foreign market? It is ultimately this question that motivates the following empirical work in this paper.

4.3.2 The Impact of FDI and Exports on International Knowledge Spillovers

Because the effects of intranational R&D spillovers were found to so completely overwhelm the effects of international spillovers in previous work, the following empirical work will focus on international spillovers. Beginning with an "innovation production function," as in equation (7),

20. This can arise because only a small fraction of the constructed spillover "pool"—all of which is presumed to be technologically relevant external R&D—actually has a positive impact on the research output of the firm.

21. See Jaffe (1986), who found direct evidence of negative "competitive" externalities in a framework similar to the one used in this paper.

22. Jaffe and Trajtenberg (1996) and Francis Narin (1995) attempted to measure the extent to which knowledge spillovers are intranational in scope by analyzing patterns of patent citations and citations in the scientific literature, respectively. Both studies found that innovators are much more likely to cite innovators located in the same country than one would expect given the distribution of scientific resources across countries, technological fields, and time. Goto and Nagata (1997) presented survey evidence that indicates Japanese R&D managers perceive other domestic firms to be more important sources of technology spillovers than foreign firms.

we drop the intranational spillover variable to yield the following log-linear equation:

$$(10) \qquad n_{it} = \beta r_{it} + \gamma(\mathrm{FDI}_{if})k_{fit} + \sum_{d}\delta_{d}D_{id} + \varepsilon_{it}.$$

Here n_{it} is innovation, r_{it} is the firm's own R&D investment, k_{fit} is the potential foreign spillover pool, the D's are dummy variables to control for differences in the propensity to generate new knowledge across industries (indicated by the subscript d), and ε is an error term. However, we hypothesize that the impact of international spillovers on innovative output, γ, is an increasing function of the stock of FDI firm i has set up in the foreign market ($\gamma'(\mathrm{FDI}_{it}) > 0$), such that Japanese firms with high levels of FDI enjoy a higher innovation output elasticity for a given level of potential knowledge spillovers. The reasoning behind this is straightforward: spillovers are not automatic. To monitor and understand other firms' R&D can be a difficult task. It may be facilitated enormously by the geographical proximity attained through FDI, through which the cost of accessing foreign firms' knowledge assets is reduced. This increase in a firm's ability to receive spillovers may occur whether or not the subsidiary is set up explicitly or entirely for the purposes of following research trends in the United States, and it may occur whether or not the FDI by the Japanese firm takes the form of greenfield new investment or acquisition of existing U.S. firms.

However, there are also both theoretical and empirical reasons for thinking that the spillover-enhancing effects of acquisition FDI and greenfield FDI are different. The possibility exists that Japanese firms establishing new production facilities abroad may have relatively little to learn from their U.S. counterparts, being more technologically advanced than these counterpart firms at the time they undertake the actual investment. On the other hand, empirical work by a number of authors has suggested that acquisition FDI is at least partly motivated by the desire to obtain the technological assets of the purchased firms. In light of this, we break down Japanese FDI into acquisition FDI and greenfield FDI and present results based on total FDI as well as acquisition FDI only. Note that we are taking a broader view of the potential spillover benefits of acquisition than others have taken in this literature. We hypothesize that by purchasing a firm in the United States, a Japanese firm not only acquires the proprietary knowledge assets of the purchased firm but is also able to use the acquisition to tap into the informal technological networks and knowledge-sharing relationships possessed by the research personnel of the acquired firm.[23]

As in previous equations, we substitute observed patents for unobserved innovation, so that we are left with

23. Porter (1990) also stressed these "access" benefits as an important component of the potential strategic benefits of acquisition.

$$p_{it} = \beta r_{it} + \gamma(\text{FDI}_{it})k_{fit} + \sum_d \delta_d D_{id} + \mu_{it}. \quad (11)$$

Again, we allow μ to contain an individual effect as well as a truly random error component.

We do not have enough degrees of freedom to allow γ to vary with either the number of subsidiaries in the United States or the number of employees in those subsidiaries. Instead, we divide our sample into firms with a "substantial" FDI presence in the United States and firms without such a presence and allow the parameter γ to vary across the two subsamples. In practice, this is done by running a regression including an interaction term in which the spillover term is multiplied by a dummy variable signifying whether the firm has "substantial" FDI in the United States.

Thus we estimate

$$p_{it} = \beta_1 + \beta_2 r_{it} + \gamma_0 k_{fit} + \gamma_1 k_{fit} * \text{fdi}_{it} + \sum_d \delta_d D_{id} + \mu_{it}, \quad (12)$$

which is the econometric analogue of equation (11). Here fdi is a dummy variable equal to one if the firm has undertaken substantial FDI in the United States by year t, and zero otherwise.[24]

In a similar fashion, we can allow the strength of the spillover term to vary with the level of exports by firm i to the U.S. market as well as the level of its FDI in the United States. In this paper, I use data on the percentage of firm sales exported to the United States as the measure of "U.S. export intensity." As in equation (12), I create an interaction term between this level of export intensity and the foreign spillover term. Here the measure of export intensity is a percentage rather than a dummy variable equal to one if the export intensity is above some threshold level. Thus I estimate

$$\begin{aligned} p_{it} = {} & \beta_1 + \beta_2 r_{it} + \gamma_0 k_{fit} + \gamma_1 k_{fit} * \text{exint}_i + \gamma_2 k_{fit} * \text{fdi}_{it} \\ & + \sum_d \delta_d D_{id} + \mu_{it}, \end{aligned} \quad (13)$$

where exint is the measure of U.S. export intensity. This provides us with a crude but potentially useful framework for comparing the spillover-enhancing effects of FDI with the comparable effects of exports.[25]

Some attention needs to be devoted to the assumed properties of the

24. FDI is measured as a cumulative count of either numbers of subsidiaries in the United States or number of U.S. employees. The FDI dummy variable is set equal to one if this cumulative count is in the upper quartile of all observations in the sample. I present results using measures based on both counts of subsidiaries and counts of employees. In results not reported in this paper, I also tried constructing an interaction term of the cumulative counts (of subsidiaries or employees) multiplied by the foreign spillover term. I obtained qualitatively similar, but statistically slightly weaker, results with this alternative formulation.

25. Note that there is no time subscript on the exint variable—we will rely on data from a single year.

new error term. Allowing the propensity to patent to vary across firms in a way not correlated with the other regressors creates a systematic component to the error—an individual effect, ξ, such that

$$\mu_{it} = \xi_i + u_{it}, \tag{14}$$

where the u is assumed to be a normal i.i.d. disturbance. If ξ_i is uncorrelated with the right-hand-side regressors, then this effect can be estimated using the random-effects framework.

One can imagine, though, that this individual effect in the propensity to patent may be correlated with a firm's own research levels. If we assume unobservable but permanent differences in the productivity of firms' research, owing perhaps to the unequal distribution of high-quality research personnel across firms, we can easily imagine that firms with high-quality research personnel will do more research and that this will lead to more patents. One can also imagine that more productive research teams might be able to more effectively monitor research developments outside the firm. More to the point, higher levels of research productivity might also lead firms to engage in more FDI. This could generate a spurious statistical relationship between high levels of FDI and higher measured output elasticities of international spillovers. In this case, estimates are biased unless we correct for the correlation between firm-specific research productivity and our other independent variables. We can do this using a fixed-effects estimator.[26] Results from both a random-effects specification and a fixed-effects specification are provided for our estimates of equation (12).

Unfortunately, the fixed-effects approach may create problems of its own. First of all, fixed-effects models effectively throw away the cross-sectional dimension of the data, obtaining identification from changes within firms over time. In this data set, most of the variance is in the cross-sectional dimension, so the cost of the fixed-effects approach is quite high. Furthermore, to the extent that measurement error is present in the data, using fixed-effects models can actually exacerbate the measurement error bias, leading to a downward bias in all estimated coefficients. Our results, presented in the next section, suggest that such measurement error bias is present.[27]

26. The obvious alternative would be some sort of instrumental variables approach. Unfortunately, the only instrumental variables available at the firm level are lagged values of the included variables. If research quality evolves slowly over time, these lagged values are likely to be no less endogenous than the variables for which we instrument. As for general method of moments "dynamic" panel estimators, which use lagged levels as instruments for current differences, Blundell and Bond (1995), among others, have found that in short, moderately sized panels with autoregressive explanatory variables (such as my data set), these estimators can behave quite badly.

27. The classic reference on this problem is Griliches and Hausman (1986).

4.4 Empirical Estimates of the Spillover-Augmenting Impact of Foreign Direct Investment and Exports

I use microdata on publicly traded high-technology manufacturing firms in the United States and Japan. Considerable anecdotal evidence suggests that Japanese firms are particularly good at monitoring R&D developments abroad. In addition, some of these Japanese firms engaged in FDI on a large scale in the United States, at least some of which was explicitly motivated by the desire to "tap into" sources of U.S. technological strength. Fortunately, there also exists broadly comparable, publicly available data at the micro level on the innovative activities of publicly traded firms in both countries.[28]

I chose to examine the five industries in the United States and Japan for which the average ratio of R&D to sales is highest, for the simple reason that one is less likely to identify the sources and effects of spillovers in industries with little technological innovation. Since I rely on patents both as indicators of innovative activity and as a means of locating firms in technology space, I restricted my sample to U.S. and Japanese firms with more than ten patents granted in the United States during my initial sample period, 1977–89. Prior to 1985, the publicly available data on Japanese firm-level R&D spending are of uneven quality, with gaps and large jumps in the time series of individual firms. Thus, in most of my regressions, I am forced to further restrict the sample period to the years 1986–89.

The Japanese panel consists of 208 firms from the chemical, machinery, electronics, transportation, and precision instrument manufacturing industries. For each firm, we have data by year for the years 1986–89. For each year, we have the number of patents granted to these firms in the United States (classified by date of application), their R&D expenditures in that year, a domestic spillover term consisting of the weighted sum of external R&D performed by technologically related Japanese firms computed for each year, and a foreign spillover term consisting of external R&D performed by technologically related U.S. firms.[29] The FDI data, originally taken from volumes of *Japan's Expanding U.S. Manufacturing Presence*, published by the Japan Economic Institute (MacKnight 1987–91), include both cumulative counts of subsidiaries and numbers of U.S.

28. Note that the data are further described in the data appendix.

29. Here I use the U.S. patents of Japanese firms to locate them in technology space and to measure their innovation. The patent classification schemes and screening processes used in the two countries are different enough that, to ensure the comparability of patents for both sets of firms, I decided to use U.S. patents. It should be noted that Japanese firms are extremely aggressive about patenting their inventions in the United States as well as Japan. Japanese firms now account for about 25 percent of new patents in the United States, by far the most important foreign users of the American patent system. Finally, it is also true that detailed data on the Japanese patents held by these firms is difficult to obtain and extraordinarily expensive. To date, I have been unable to obtain a useful quantity of such data.

Table 4.1 Sample Statistics for Japanese Firms with U.S. FDI

Variable	Mean	Standard Deviation	Minimum	Maximum
Patents	95	179.3	0	966
R&D[a]	33,728.24	59,553.57	0	316,148
R&D/sales	.046	.025	0	.16
U.S. employees	1,069	1,870.3	0	12,233

[a]Unit is millions of 1985 Japanese yen.

Table 4.2 Sample Statistics for Japanese Firms without U.S. FDI

Variable	Mean	Standard Deviation	Minimum	Maximum
Patents	11	26	0	386
R&D[a]	4,844.65	7,969.15	100	82,152.65
R&D/sales	.043	.030	.002	.16

[a]Unit is millions of 1985 Japanese yen.

employees.[30] Tables 4.1 and 4.2 give some summary statistics for the Japanese sample.[31]

The foreign spillover term is based on firm-level data from a panel of 209 U.S. firms in the same five industries covering the same years. The construction of this U.S. data set is further described in the data appendix. Complete documentation of the data and original sources can be found in Branstetter (1996).

4.4.1 Sample Statistics

Tables 4.1 and 4.2 show that firms with FDI in the United States tend to be larger, obtain more patents, and have higher levels of R&D spending, both in absolute terms and as a percentage of sales.[32] The difference in

30. I am grateful to Thomas Pugel for providing me with these data in electronic form.

31. The use of U.S. patents to infer the R&D activities of Japanese firms raises the possibility that I am systematically undermeasuring Japanese research productivity. To the extent that the Japanese patent only a fraction of their inventions in the United States but this fraction is constant across firms and across time, it will fall into the constant term (since I estimate separate knowledge production functions for U.S. and Japanese firms). To the extent that it is constant across firms but not across time, it will fall out in the time dummies. To the extent that it is not constant across firms but is constant across time, this differential will be absorbed into the fixed effect. In the absence of more detailed information about the Japanese patents of Japanese firms, little more can be said on this issue, though I acknowledge that it may cloud my interpretation of the empirical results.

32. I note here that FDI is measured as a "cumulative" count of both subsidiaries and U.S. employees. Firms with a "significant presence" are those that obtain a level in the upper quartile of total observations. A number of firms moved from positions of no U.S. FDI to significant amounts over the course of the sample period, so there is substantial time variation in the fdi/foreign-spillover interaction term.

patenting is especially pronounced. In addition, not surprisingly, industry mix differs across the two subsamples, though this is not shown in the tables. Because the two groups of firms differ in many ways other than their levels of FDI, it may be necessary to use a fixed-effects approach in order to avoid erroneously attributing differences in the impact of spillovers to FDI because of omitted-variables bias.

4.4.2 Regressions Using Total Foreign Direct Investment

Table 4.3 gives the results of a number of alternative specifications of equation (12), where FDI is measured as the sum of greenfield investment, joint ventures, and acquisitions. The first two columns of table 4.3 show the results of OLS regressions on own R&D, the foreign spillover term, and the interaction term of the FDI dummy variable together with the foreign spillover term.[33] The first column gives results from a regression run without time dummies. The second column includes time dummies. The results, which are essentially confirmed in all other specifications, indicate that possession of an "FDI presence" in the United States does increase the innovative output of foreign spillovers, but only by a small amount. The coefficients can be interpreted as elasticities, so the reported numbers imply that if the amount of foreign spillovers were to increase by 10 percent, the innovative output of Japanese firms would go up by 2 percent, but the additional impact obtained by Japanese firms with a substantial FDI presence would only be 0.4 percent.

The third and fourth columns of table 4.3 illustrate the results from a random-effects specification. The coefficient on the fdi/foreign-spillover interaction term remains essentially unchanged in both columns. The fourth column reveals, however, that the estimated impact of foreign spillovers is quite sensitive to the inclusion of a domestic spillover term. When domestic spillovers are controlled for, the estimated coefficient on the overall foreign spillover term becomes negative, though it also is no longer statistically significant at the traditional 5 percent level. However, the fdi/foreign-spillover interaction term remains positive and significant.

Given our earlier concerns about the likelihood of firm-specific differences in research productivity, however, it may be that the random-effects coefficients are affected by the omitted-variables bias arising from the correlation of this unmeasured firm-specific research productivity with R&D inputs, innovative outputs, and FDI. If we assume that these firm-specific variables change slowly over time—so slowly that they can be assumed to be fixed over the 1986–89 four-year span of our data—then fixed-effects models will yield consistent estimates. Unfortunately, to the extent that

33. In these regressions, the foreign spillover term is lagged one period, partly to control for differences in fiscal years between U.S. and Japanese firms and partly to allow foreign knowledge more time to spill over.

Table 4.3 **Linear Regressions Based on Total Japanese FDI Data Measured by Counts of U.S. Subsidiaries**

Variable	OLS (Foreign)	OLS (Foreign)	Random Effects (1)	Random Effects (2)	Fixed Effects (1)	Fixed Effects (2)
log R&D	.6760	.6752	.5842	.5544	.1315	.1292
	(.0286)	(.0288)	(.0435)	(.0436)	(.0894)	(.0893)
log Domestic spillovers				1.074		.5353
				(.2702)		(.3282)
log Foreign spillovers	.2057	.2094	.3991	−.5341	.7755	.2126
	(.0952)	(.0961)	(.1695)	(.2868)	(.3196)	(.4701)
log Foreign spillovers *fdi	.0401	.0403	.0309	.0311	.0225	.0220
	(.0059)	(.0060)	(.0058)	(.0057)	(.0064)	(.0064)
Chemicals	−.6610	−.6602	−.6410	−.2488	n.a.	n.a.
	(.1499)	(.1501)	(.2732)	(.2857)		
Machinery	−.2959	−.2958	−.2923	−.2004	n.a.	n.a.
	(.1597)	(.1599)	(.2911)	(.2865)		
Electronics	−.5347	−.5355	−.5234	−.5762	n.a.	n.a.
	(.1522)	(.1525)	(.2784)	(.2735)		
Transportation	−.6952	−.6964	−.6567	−.5855	n.a.	n.a.
	(.1590)	(.1593)	(.2896)	(.2847)		
Year 2		−.0071	−.0534	.0879		
		(.0966)	(.1054)	(.0572)		
Year 3		.0332	.0365	.0422		
		(.0973)	(.1028)	(.0544)		
Year 4		−.0405	.0648	−.0632		
		(.0985)	(.1025)	(.0593)		

Note: Dependent variable is the log of the number of patents. $N = 832$. Numbers in parentheses are standard errors.

measurement error is present in the data, using a fixed-effects model could actually exacerbate the measurement error bias.

The fifth and sixth columns reveal the results obtained when one uses fixed-effects models. It is noted that the magnitude and significance of the own R&D term drops substantially, suggesting that measurement error is indeed present and the resulting bias is considerably worsened by using the fixed-effects approach. Again, the estimated impact of the foreign spillover term is quite sensitive to inclusion of domestic spillovers. When domestic spillovers are controlled for in the fixed-effects specifications, the overall foreign spillover term is no longer significant. However, the fdi/foreign-spillover interaction term remains positive and significant in all specifications.

4.4.3 The Negative Binomial Estimator

Linear estimators have the two considerable advantages of ease of estimation and interpretation and relative robustness to misspecification of

Table 4.4 **Negative Binomial Model Based on Total Japanese FDI Data Measured by Counts of U.S. Subsidiaries**

Variable	Negative Binomial
log R&D	.7420
	(.0291)
log Domestic spillovers	1.245
	(.1811)
log Foreign spillovers	−.8232
	(.1753)
log Foreign spillovers *fdi	.0295
	.0062
Chemicals	−.4713
	(.1769)
Machinery	−.2083
	(.1666)
Electronics	−.8794
	(.1555)
Transportation	−.5833
	(.1645)
Time dummies	Yes
α	.8978
Log likelihood	−2,988.69

Note: Dependent variable is the number of patents. $N = 832$. The negative binomial regressions follow Hausman, Hall, and Griliches (1984). Numbers in parentheses are standard errors, computed from the analytic second derivatives.

the nature of the error term. However, patent data are intrinsically "count" data, for which the normal distribution is likely to be an inappropriate approximation.[34] Over the past ten years, econometricians have developed a number of count data models to deal with such data. Among the most commonly used is the negative binomial estimator. The negative binomial estimator is a generalization of the familiar Poisson estimator.[35] Provided the assumption that the error term follows a negative binomial distribution is met, consistent estimates of the parameters of interest can be obtained through maximum likelihood estimation. Of course, if the distributional assumption is incorrect, then consistency is not assured, even in theory. Therefore, evidence from a negative binomial regression is offered in table 4.4 as a reality check on the linear results rather than as a superior alternative to linear estimation.

34. An additional problem arises from the fact that some Japanese firms take out no patents in some years—and the log of zero is undefined. In this analysis, this problem is addressed by simply setting the dependent variable equal to zero in such cases. Concerns that this transformation might affect results constitute an additional reason for using the negative binomial specification as a "robustness" check.

35. See Hausman, Hall, and Griliches (1984) for a derivation of these models and a discussion of their relative merits.

Fortunately, the results broadly corroborate those of the linear models. In this specification, as in others, there is no evidence of positive, significant foreign spillovers overall, but the fdi/foreign-spillover interaction term remains positive and significant.

4.4.4 Results from Acquisition Foreign Direct Investment and Other Robustness Checks

A number of theoretical and empirical papers on Japanese FDI have suggested the importance of breaking down Japanese FDI by category into greenfield investment and acquisition FDI. It has been suggested by some authors, including Blonigen (1997), that greenfield investment is likely to be motivated by the technological strengths of the investing Japanese firms rather than the relative technological strengths of the U.S.-based competitors. In fact, one could make a loose, heuristic argument on the basis of internalization theory that Japanese firms would be motivated to undertake the most greenfield FDI precisely where their U.S. counterparts were technologically weakest, in a relative sense. Therefore, there is little relevant technological innovation that could be expected to spill over to the more advanced Japanese firms.

On the other hand, as we have mentioned previously, there is some evidence that acquisition FDI is at least partly motivated by the desire to tap into sources of U.S. relative technological strength. For that reason, we constructed alternative measures of Japanese FDI using only data on acquired subsidiaries. The results of linear regressions using these data are given in table 4.5.

The layout of this table is similar to that of table 4.3, and the empirical

Table 4.5 **Linear Regressions Based on Japanese Acquisition FDI Data Measured by Counts of U.S. Subsidiaries**

Variable	OLS (1)	OLS (2)	Random Effects (1)	Random Effects (2)	Fixed Effects (1)	Fixed Effects (2)
log R&D	.7280	.7288	.6092	.5808	.1461	.1429
	(.0277)	(.0279)	(.0437)	(.0437)	(.0902)	(.0901)
log Domestic spillovers				1.057		.5146
				(.2755)		(.3304)
log Foreign spillovers	.2510	.2474	.4336	−.4831	.8807	.3448
	(.0967)	(.0978)	(.1733)	(.2925)	(.3175)	(.4679)
log Foreign spillovers*fdi	.0235	.0230	.0249	.0244	.0199	.0189
	(.0067)	(.0068)	(.0064)	(.0064)	(.0070)	(.0071)
Industry dummies	Yes	Yes	Yes	Yes	n.a.	n.a.
Time dummies	No	Yes	Yes	Yes	No	No

Note: Dependent variable is the log of the number of patents. $N = 832$. Numbers in parentheses are standard errors.

Table 4.6 **Negative Binomial Model Based on Japanese Acquisition FDI Data Measured by Counts of U.S. Subsidiaries**

Variable	Negative Binomial
log R&D	.7921
	(.0285)
log Domestic spillovers	1.258
	(.1809)
log Foreign spillovers	−.7954
	(.1768)
log Foreign spillovers *fdi	.001
	(.0027)
Industry dummies	Yes
Time dummies	Yes
α	.9211
Log likelihood	−3,000.1

Note: Dependent variable is the number of patents. $N = 832$. Numbers in parentheses are standard errors.

specifications are the same. By and large, the results are qualitatively identical to those in table 4.3, although the impact of acquisition FDI seems slightly smaller in estimated elasticity terms. The first two columns show the results of OLS regressions of patent output on own R&D, foreign spillovers, the interaction term, and industry dummies, with and without time dummies. The second two columns give the results of the random-effects models. Again, the foreign spillover term is quite sensitive to the inclusion of information on domestic spillovers, whereas the fdi/foreign-spillover term remains quite robust to it. Finally, the fixed-effects models demonstrate the same patterns as the fixed-effects models of table 4.3.

Table 4.6 gives the results of a negative binomial regression using the acquisition FDI data. As the reader can easily see, here too the results are broadly consistent with those obtained from the negative binomial specification that employed total FDI numbers. However, the estimated impact of FDI on spillovers is not statistically significant at conventional levels. Finally, table 4.7 gives the results of linear regressions using total FDI data where the FDI variable is based on numbers of U.S. employees rather than counts of subsidiaries.[36] The results are quite similar to those obtained using counts of subsidiaries as the measure of FDI.

36. Again, the FDI variable is a dummy variable, but here it is set equal to one where a firm lies in the upper quartile in terms of its number of U.S. employees rather than its number of U.S. subsidiaries.

Table 4.7 **Linear Regressions Based on Japanese Total FDI Data Measured by Total Number of U.S. Employees**

Variable	OLS (2)	Random Effects (1)	Fixed Effects (1)	Fixed Effects (2)
log R&D	.6760	.5852	.1542	.1514
	(.0297)	(.0437)	(.0904)	(.0903)
log Domestic spillovers				.5654
				(.3289)
log Foreign spillovers	.2385	.4046	.8740	.2747
	(.0966)	(.1707)	(.3166)	(.4710)
log Foreign spillovers*fdi	.0395	.0336	.0221	.0217
	(.0069)	(.0066)	(.0074)	(.0075)
Industry dummies	Yes	Yes	n.a.	n.a.
Time dummies	Yes	Yes	No	No

Note: Dependent variable is the log of the number of patents. $N = 832$. Numbers in parentheses are standard errors.

4.4.5 The Impact of Export Intensity versus Foreign Direct Investment on Knowledge Spillovers

In this subsection, we present the results of a preliminary investigation of the impact of export intensity on a firm's ability to absorb R&D spillovers from U.S. firms. This effect is compared to that obtained from FDI. Our analysis here is limited by the fact that data at the firm level on exports broken down by region of export destination are only available for a subsample of our firms.[37] These data are taken from reports filed by Japanese firms that are listed on the Tokyo Stock Exchange, and they are currently only available for firms in the electronics sector.[38] Furthermore, these data record export levels in the year 1992.

In the regressions, shown in table 4.8, we create an interaction term in which our international spillover measure is multiplied by the percentage of total sales of the company that was exported to the U.S. market in 1992, as we specified in equation (13). We are implicitly assuming that this percentage of sales exported to the United States in 1992 is a reasonable proxy for the company's exports to the United States in the years of our sample period, 1986–89. To the extent that this assumption fails to hold, our export/spillover interaction term is measured with error.

In table 4.8, we run a number of versions of equation (13), using both OLS and random-effects regressions. The results are not robust to the use of fixed effects. Given the small sample size used in this regression, that

37. I thank René Belderbos for generously providing me these data in electronic form.
38. The data are originally taken from the *Yuka Shouken Hokokushou* filed by individual companies.

Table 4.8 Exports versus FDI as Channels of R&D Spillovers

Variable	OLS	Random Effects	Random Effects	Random Effects
log R&D	.844	.625	.588	.503
	(.067)	(.100)	(.101)	(.043)
log Foreign spillovers	−.229	.181	−.947	
	(.181)	(.325)	(.649)	
log Foreign spillovers from FDI	.075	.077	.077	.030
	(.013)	(.014)	(.013)	(.006)
log Foreign spillovers from exporting	.252	.329	.130	.359
	(.069)	(.129)	(.160)	(.072)
log Domestic spillovers			1.59	.545
			(.763)	(.152)
Industry dummies	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes

Note: Dependent variable is the log of the number of patents. $N = 188$. Numbers in parentheses are standard errors.

result does not surprise us. In future research, with a larger sample of firms with both export and FDI data, we expect to find more robust results of the impact of export intensity on spillovers. As can be clearly seen from these preliminary results, in all cases the coefficient on the export-intensity/spillover interaction term is quite large relative to that of the fdi/spillover interaction term. Of course, in the form in which they are given in table 4.8, the two sets of coefficients are not strictly comparable. However, the estimated export-intensity/spillover interaction terms imply that evaluated at the mean of the data, the elasticity of patent output with respect to the foreign knowledge spillover term increases by 2 to 5 percentage points for every percentage point increase in U.S. export intensity. This suggests that exports *may* be a more important channel of R&D spillover than is FDI for Japanese firms.[39] Alternatively, one can argue that having already achieved a high degree of "contact" with the U.S. market, Japanese firms found little additional value in terms of increased "spillover absorption capacity" from their U.S. foreign investments.

4.5 Conclusions and Extensions

The primary results of the regressions undertaken in this paper can be simply stated. Having an FDI presence in the United States seems to augment the R&D spillovers Japanese firms are able to obtain from the research efforts of U.S. firms. However, the estimated effects, while quite

39. This needs to be tempered with the observation that the construction of the two interaction terms differs. Thus some care must be taken in the interpretation of these coefficients.

robust to alternative empirical specifications and alternative measures of FDI, tend to be quite small. In particular, they do not seem to be large enough to provide evidence in favor of the alarmist position of some American observers that Japanese firms have been able to secure competitive advantages by tapping into U.S. technological strengths. Instead, the evidence presented in this paper suggests that even those Japanese firms with a comparatively large stock of FDI in the United States tend to learn more from other Japanese firms than they do from their U.S. counterparts.

The much more preliminary results presented here on the impact of exports suggest that firms with high levels of exports to the U.S. market seem to receive more in the way of knowledge spillovers than firms without such high levels of exports. These results are based on information from a much smaller sample drawn from a single industry. Nevertheless, they could help us to interpret the results in the previous paragraph. It may be that Japanese firms were already well aware of developments in U.S. markets through their extensive exports to the United States. The additional learning obtained through actual establishment of manufacturing facilities may have contributed little to a level of sophistication concerning U.S. markets that was already high by the time the investment wave began in the late 1980s.[40] Redoing the export regressions with a larger data sample is the subject of current research.

Of course, all of these results need to be assessed in light of a number of important caveats. First, I do not possess R&D and patenting data on all Japanese firms that engaged in substantial FDI in the United States. To the extent that the missing Japanese investors were able to obtain substantially greater spillover benefits than the firms in my data set, I may be systematically undermeasuring the effects. I am currently gathering data in order to expand the cross-sectional dimension of this data set and hope to include that data in future work. Second, the data on foreign spillovers come from a panel of large U.S. R&D-performing firms, not the firms wholly acquired by Japanese purchasers. It is possible that acquiring Japanese firms obtained substantial benefits from their acquisitions but that the more indirect spillover-enhancing benefits I am looking for were not present. In principle, data on the patent portfolios and R&D spending of firms that were publicly traded prior to their acquisition by Japanese firms could be obtained from Compustat and other sources. I hope to investigate this possibility in future research. Third, the data series used in this paper ends in 1989, the year in which investment peaked. It is reasonable to think that the spillover benefits from investment or acquisition may not begin to affect the parent firm's innovative activity until several years after the investment or acquisition. If this is the case, then my time-series di-

40. In light of the relative paucity of data, these conclusions must remain tentative.

mension may be too short to capture the impact of the data. I am currently gathering data that will allow me to extend this analysis through the mid-1990s.

Of course, any extension of the data series into the 1990s will have to deal with the effects of the *Heisei* recession, which may swamp any of the positive effects of FDI on domestic innovation. As an additional caveat, it may be that the spillover-augmenting benefits obtained through foreign production plants are small, but the spillover-augmenting benefits obtained through research centers set up in other countries might be quite substantial. In the 1990s, leading Japanese corporations set up research centers in Silicon Valley and other areas expressly for the purpose of more closely following research trends in American high-technology industries. I am currently attempting to obtain data on these research subsidiaries in order to separate out their effects in future research.[41]

A number of extensions could be made to the work presented here. One particularly useful extension would be to use a more direct measure of knowledge spillovers. While Jaffe's (1986) framework has a number of desirable and useful features, spillovers are inferred rather than measured directly. In principle, it is possible to measure knowledge spillovers directly by observing the extent to which the patents of Japanese firms cite the patents of U.S. firms, both those they have acquired and those that remain independent competitors.[42] If we find that Japanese firms with a substantial FDI presence cite U.S. patents more frequently, this would be far more direct evidence of "spillover augmentation through FDI" than could be possibly obtained through the use of Jaffe's (1986) framework. I hope to pursue this alternative approach in future work.

An important omission in this paper was any consideration of the extent to which Japanese FDI served as a means by which technology spillovers flowed from Japanese firms to indigenous U.S. producers. Anecdotal evidence suggests that this effect may have been important in the auto industry, though empirical research has not given strong support to this view. In principle, the data and the empirical techniques used in this paper could be used to investigate this point. I hope to explore this question in future work as well.

Many countries and some subnational regions are actively soliciting foreign investment, offering tax incentives and other economic inducements, often in search of spillover benefits of technology from foreign investors. However, the real extent to which FDI functions as a channel of technology spillovers, either from investor to the host country or from host country firms back to the parent company of the investor, remains undeter-

41. R&D affiliates established abroad are the subject of a recent study by Kuemmerle (1997).

42. Analysis of knowledge spillovers using patent citations was undertaken by Jaffe and Trajtenberg (1996), among others.

mined. In spite of the formidable measurement challenges, it is important that economists attempt to quantify these benefits. I hope that this paper might stimulate other economists to use the kinds of data and the empirical techniques employed here to attempt to answer these extremely important questions.

Data Appendix

Data on U.S. firm sales, capital stock, R&D spending, and other factors were taken from the NBER Productivity Data Base created by Bronwyn Hall and others. Documentation for the NBER database is available online or in written form, and I will not reproduce it here. The patent data for U.S. firms were collected in the same manner as that for Japanese firms, which is described below. I identified the subsidiaries of the U.S. firms in my database using multiple editions of the *Directory of Corporate Affiliations.*

Data on Japanese firm sales, capital stock, employment, and other inputs were taken from the Japan Development Bank Corporate Finance Data Base. This proprietary database, collected and maintained by the Japan Development Bank, is an extremely rich firm-level panel data set containing information on hundreds of variables for thousands of firms from all sectors of the Japanese economy. Due to the well-known problems of output and productivity measurement in many service sector industries as well as the fact that most private R&D is concentrated in the manufacturing sector in both the United States and Japan, I chose to focus solely on manufacturing firms.

Data on Japanese R&D spending are taken from Japanese-language primary sources, namely, the *Kaisha Shiki Ho,* published by Toyo Keizai, and the *Nikkei Kaisha Joho,* published by the Nihon Keizai Shimbunsha. Both are quarterly published books of statistics on Japanese publicly traded firms. Responding to interest in the investor community in the R&D spending of Japanese firms, both books began publishing the results of annual surveys on R&D spending, in the early 1980s and late 1970s, respectively. Response to the surveys is voluntary, so coverage varies from year to year. Furthermore, firms are not legally required to submit precisely accurate figures when they do choose to respond. Nevertheless, knowledgeable Japanese sources contend that these books do provide reasonably accurate information.

Data on the U.S. patents of Japanese firms were obtained in electronic form from the U.S. Patent Office. Patents were obtained using the CASSIS CD-ROM. These patents were later reclassified by date of application, using application data supplied by Adam Jaffe. These data had to be matched to the other microdata firm by firm, since patents are classified by the English name of the Japanese firm (and occasionally the English transliteration of the Japanese name) or by that of one of its subsidiaries, while my other data are classified by the Tokyo Stock Exchange code, which is the Japanese equivalent of the Compustat code. In identifying subsidiaries, I relied on the information from *Kigyo Keiretsu Soran,* published by Toyo Keizai, as well as the source *Kigyo Keiretsu to Gyokai Chizu* and the book *Industrial Groups in Japan,* published by Dodwell Marketing Consultants. The problem of matching patents to firms was simplified since a number of large research-intensive subsidiary firms were listed separately in my relatively disaggregated data.

Data on Japanese FDI in the United States were graciously provided to me in electronic form by Thomas A. Pugel of the Stern School of Business at New York University. The original source of Pugel's data is the publication *Japan's Expanding U.S. Manufacturing Presence: 1990 Update,* which was produced by the Japan Economic Institute. Despite its title, this book also provides some data on Japanese subsidiaries that were *planned* by 1990 but not actually established until later. This source provides much useful data on Japanese subsidiaries, including the name of the Japanese parent firm, the address of the subsidiary, the date of establishment of the subsidiary, the number of employees of the subsidiary, and a brief description of the subsidiary's primary businesses.[43] Unfortunately, information on all of these variables is not always available for all subsidiaries. Data on subsidiaries were matched to other data for Japanese companies based on the name of the firm. This matching was done using a computer algorithm that keyed in on fragments of firm names. Where necessary, the matching was corrected by hand. As these data focus on Japanese direct investment in U.S. manufacturing, it is not a comprehensive data source. It is possible that some nonmanufacturing investments by Japanese manufacturing firms were missed in these data.

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Comment Akiko Tamura

In this paper, Branstetter presents a very interesting and powerful treatment of empirical facts that invites the reader to extend to other data sets or samples.

The most interesting finding in this paper is that the effects of international R&D spillover are greater on the innovative output of Japanese firms with FDI in the United States than for other Japanese firms. This can be seen clearly from the empirical results; the coefficient on the fdi/foreign-spillover interaction term is significantly positive and very robust for all regressions. The coefficient estimate is surprisingly unchanged for all regressions except in table 4.6, which reports a much smaller number for the coefficient estimate in the negative binomial model based on Japanese acquisition FDI data. However, the amount of fdi/foreign-spillover impact is quite small; the coefficient estimates are around 0.02 to 0.04.

The FDI function as a channel for spillovers is very important. In this paper, the technology spillovers from host country to parent company, from U.S. firms to Japanese firms, is examined. I agree that this channel is significant in acquisition FDI cases. Japanese firms will purchase American firms for the purpose of getting their technology. On the other hand, technology spillovers from investors to host country firms will be significant in greenfield FDI cases. When we research Japanese FDI in other countries, especially East Asian countries, the channel of technology spillovers from Japanese investor firms to host country firms is considered

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more essential. Thus technology spillover from Japanese firms to U.S. affiliate firms should be also examined when Japanese firms establish new production facilities in the United States. However, the impact of acquisition FDI on foreign spillover is smaller than that of greenfield FDI, as can be seen by comparing the regression results in table 4.5 and table 4.3. It would be interesting to investigate why the empirical results conflict with the above intuitive understanding of the differences between the roles of greenfield and acquisition FDI.

It might also improve our understanding of the empirical results to consider domestic spillover and foreign spillover. When domestic spillovers enter the regressions, the coefficient of foreign spillover becomes negative or insignificant. This may suggest that domestic spillovers overwhelm foreign spillovers. When the R&D spending patterns of Japanese firms and U.S. firms are very similar, domestic spillover and foreign spillover will be correlated and the multicollinearity will affect the regressions.

I would like to comment on the use of data on the number of patents granted as the dependent variable. For reasons of availability, the data consist of U.S. patents held by Japanese firms instead of Japanese patents. From the aggregate 1991 data supplied by the Japanese Patent Office, Japanese patents granted in Japan numbered 30,453,000 and Japanese patents granted in the United States numbered 21,027,000. These numbers are close enough to allow us to assume that Japanese firms patent most of their inventions in the United States as well as in Japan.

However, it is possible that the number of patent *applications* would be a better measure of innovation than the number of patents granted. One reason why patent applications might present a clearer picture is the time lag between the invention and the granting of its patent. In addition, many Japanese patent applications never request examination for a grant because it is felt that the application already supplies some protection by simply having been submitted and does not need to be granted. According to data supplied by the Japanese Patent Office (1994), only 9 percent of applications filed in 1991 requested examination for a grant by 1993. Some patent applications may be useless, but it is difficult to determine the quality of patent applications. The number of Japanese patent applications in Japan, 335,933,000, is much larger than Japanese patent applications in the United States, 38,609,000. The number of Japanese patent applications is so large partly because Japanese patents contain fewer claims per patent. As the author mentioned in the paper, the differences between the Japanese and U.S. patent systems should be considered carefully.

Branstetter carefully constructs a measure of knowledge spillovers, which itself can be considered an excellent contribution of this paper. Although it will be less impressive, I would like to present some facts concerning the relation between knowledge spillover and FDI from a much simpler, more straightforward perspective. If Japanese firms with FDI in the United States cite U.S. patents more frequently, knowledge spillovers from the United States to Japan are augmented. Correspondingly, if U.S. affiliates of Japanese firms license Japanese patents, the knowledge spillover is from Japan to the United States. A survey by Japan's Science and Technology Agency (1997) reports on Japanese technology imports and exports, mostly giving the payment amounts from patent licensing, including initial payments and ongoing royalties. From the data for 1995, about 30 percent of Japanese technology exports to the United States were directed toward affiliates. On the other hand, most Japanese technology imports, more than 95 percent, are from nonaffiliate firms. These surveys are much less complete than the data Branstetter has. However, the technology import data puzzle me a little in terms of technology transfer from U.S. affiliates to Japanese parent firms. (More complete data for Japanese technology exports and imports are available from Japan's Management and Coordination Agency [1997], but the data do not show whether the firms export/import technology from affiliate or nonaffiliate firms.)

Since Branstetter gets remarkable results from his empirical work, extending his analytical tools to other data sets, such as data on Japanese firms with FDI in other countries, would be fascinating. Can the findings in this paper, the relations between technology spillover and FDI, apply to Japanese firms with FDI in East Asian countries? Collecting such data as Branstetter used in the paper would be extremely difficult, so we may have to begin with industry-level aggregate data instead of data on individual firms.

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Comment Mariko Sakakibara

This paper begins by distinguishing between two types of FDI: the first is home-base-exploiting FDI, based on the internalization theory first devel-

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oped by Hymer (1960). In this type of FDI, the formation of multinational enterprises (MNEs) is tied to the existence of firm-specific advantages, which provide these firms with offsetting cost advantages and market power over foreign producers. Intangible assets such as sales and marketing or technological resources are subject to market imperfections, and the creation of internal markets across national boundaries for the exploitation of these assets gives rise to MNEs (Caves 1971; Buckley and Casson 1976). The second type of FDI is home-base-augmenting FDI, proposed by Porter (1990). In this type, the objective of FDI is to tap superior host country knowledge and learn from it. This distinction has been examined by Wesson (1993) and others.

Based on this distinction, Branstetter intends to measure the home-base-augmenting effect of FDI. Assumptions made here are that acquisitions might be a more effective means for home-base-augmenting FDI, while home-base-exploiting FDI is more likely to be conducted through greenfield investments. Branstetter finds that for both aggregate FDI and acquisition FDI, FDI-intensive firms benefit more from foreign spillovers. Though this effect is small, it is robust. In this analysis, foreign spillovers are measured as the sum of R&D efforts conducted by U.S. firms, weighted by the technological proximity to a "receiving" Japanese firm.

I would like to pose a fundamental question: Why do Japanese firms want to learn from U.S. firms through acquisitions? Branstetter's implicit assumption here, indicated by his construction of technological proximity measures, is that U.S. firms have more advanced technological knowledge in the same technological areas as the Japanese acquiring firms. This assumption might imply that technologically inferior firms want to acquire superior firms or, more realistically, larger firms want to acquire small but technologically competent firms. A more plausible and perhaps more prevalent scenario, however, is that U.S. firms have knowledge in different technological areas from Japanese acquiring firms. If this scenario is indeed more prevalent, it is necessary to add another dimension to the analysis.

The distinction between acquisition of a firm in the same business as the acquiring firm (the existing business case) and acquisition of a firm in a different business from the acquiring firm (the diversification case) provides additional insight into the process of knowledge transfer through acquisitions. Table 4C.1 illustrates the importance of this distinction.

If a firm possesses a firm-specific advantage (i.e., the home-base-exploiting FDI case), it may invest in a U.S. firm in the same business, as with the NKK–National Steel acquisition, in order to utilize its expertise in its business. In this case of home-base-exploiting FDI, it is unlikely that a Japanese firm will invest in a different business unless it wants to conduct portfolio investment.

On the other hand, in the case of home-base-augmenting FDI, Japanese

Table 4C.1 Existing Business versus Diversification

FDI Type	Existing Business	Diversification
Home-base-augmenting FDI	Yamanouchi–Roberts Pharmaceutical (perhaps limited cases?)	Sony–Columbia Pictures Kubota–Akashic Memories (hard disk drives)
Home-base-exploiting FDI	NKK–National Steel	∅

investment in the same business in the United States would be limited, as with Yamanouchi Pharmaceutical's acquisition of a smaller pharmaceutical firm. What might be more prevalent is acquisition for diversification, as with the Sony–Columbia Pictures case or the farm equipment company Kubota's acquisition of a hard disk drive company. In these cases, the Japanese firms will learn R&D capabilities different from those they already have, and so the technological distance between a Japanese firm and the U.S. spillover pool should be calculated as the distance between a U.S. subsidiary and the spillover pool it is tapping. Since Branstetter does not make a distinction between the existing business and diversification cases, technological distance is measured from the Japanese headquarters in both cases. This can be a source of measurement error.

As for the small but robust effect of foreign spillovers on Japanese FDI-intensive firms, Branstetter interprets the presence of subsidiaries in the United States as contributing to the R&D productivity of a Japanese firm through learning. Given the possible measurement error explained above, this analysis might capture the effect that foreign presence brings firms greater revenue or profit; further, if economies of scale in R&D are present, the greater R&D input will increase R&D productivity. If this is true, it is not a learning effect, as interpreted.

My suggestion is to modify the current model to reflect the actual learning process. Perhaps Branstetter can assign different weights to the distance between a Japanese firm and the U.S. spillover pool by the type of U.S. subsidiary. Alternatively, he can use another measure of spillovers: patent citation, which might be a more direct measure of spillovers.

There already exists a literature that measures the learning effect of FDI by using patent citations. Almeida (1996) examined the U.S. semiconductor industry and found that foreign subsidiaries in the United States cite more local knowledge than would be expected given the geographic distribution of innovative activities and also cite more locally than U.S. firms. He also found evidence that foreign subsidiaries in the United States contribute to local knowledge; that is, foreign subsidiaries are cited more locally than would be expected. Frost (1995) conducted a similar analysis for broader industries.

In addition to the issue of the learning process, I would like to point out a minor issue. Branstetter deals with technological proximity between

Japanese and U.S. firms. There is another proximity issue: geographical proximity in the United States, or the geographical distance between a Japanese subsidiary and the U.S. spillover pool. This would be a larger issue in the United States than in Japan, given the large size of the country. For example, if a Japanese firm wants to learn semiconductor technology, it will benefit more from establishing a subsidiary in Silicon Valley than in Kentucky. Different geographical locations of Japanese subsidiaries might have differential effects on learning.

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