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# INTERNATIONAL SPILLOVERS, KNOWLEDGE ACQUISITION AND TRANSFER AMONG JAPANESE FIRMS IN THE UNITED STATES

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**Abstract.** In this paper, we investigate (i) the relationship between international spillovers and knowledge acquisition, and, (ii) intra-firm subsidiary-to-parent transfer of technology among Japanese firms in the United States. Using a survey of 185 firms, probit regressions reveal that R&D personnel and market power significantly influence the acquisition of knowledge associated with basic and applied science and product development. Tacit knowledge that resides in customers, and skilled personnel are effective sources for exploitation of international knowledge spillovers. Participation in seminars and conferences also enhances the acquisition of applied science. Firms that rely on codified sources are unlikely to acquire any knowledge. This research also confirms other authors' findings that subsidiary autonomy facilitates knowledge acquisition. In addition, knowledge in product development is most likely to lead to vertical intra-firm transfers while applied scientific research only results in the transfer of R&D capability. Scientific team visits from the US to Japan support subsidiaries' transfer of R&D capability but teams sent from Japan to the US adversely affect transfers. Overall, our results suggest international spillovers are predominantly associated with the acquisition of tacit knowledge, and intra-firm transfers are most effective in the context of knowledge acquired in applied research and product development.

**Keywords:** International spillovers, knowledge acquisition, intra-firm transfer, Japanese subsidiaries, United States.

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## 1. Introduction

How firms acquire and transfer knowledge as well as technology has attracted attention among economists and management scholars studying innovation (Vega-Jurado *et al*. 2009; Phene, Almeida 2008). The literature identifies spillovers as a major mechanism through which firms transfer and acquire knowledge. Theories of endogenous technological change (Grossman, Helpman 1994) demonstrate that since knowledge and technology are partially public, then knowledge can be acquired or produced by another firm without incurring large additional costs. Such spillover effects have attracted much attention but are typically studied using secondary data (e.g. Anselin *et al*. 1997; Botazzi, Peri 2003). These studies also tend to focus on localized geographical spillovers. In this paper, we propose that international spillovers are becoming significant channels for Japanese multinational enterprises (MNEs) seeking to build their knowledge stock. Such spillovers are achieved through the international sourcing activities of subsidiaries. As such, our first objective is to examine Japanese subsidiaries' knowledge and technology acquisition behavior in the United States (US). Second, MNE's knowledge stock increases if subsidiaries are able to transfer sourced technology back to parent companies in the home country. Yet there are few empirical studies of reverse intra-firm knowledge flows. Our second objective is to examine if modes of knowledge acquired by Japanese subsidiaries in the US have been successfully transferred to parent firms. The paper draws from a survey of 185 subsidiaries undertaken by the authors. Most studies on Japanese MNCs in the US are based on surveys conducted by Japan's Ministry of Trade and Industry surveys (e.g. Iwasa, Odagiri 2004; Todo, Shimizutani 2008). Hence our dataset represents one of the few primary datasets outside of institutional-oriented data.

Early economic studies note that parent firms first develop at home, and then transfer technology to their subsidiaries abroad (Mansfield, Romeo 1980). Studies of the internationalization of innovation in the past have been centered on the nature of knowledge flows from home to host countries. The work of Belderbos and his colleagues (2008) on the internationalization of Japanese R&D, for instance, captures this body of work that emphasizes intra-firm parent to subsidiary transfer of technology. More recently, the business and management literature has found that when oversea subsidiaries are given significant levels of autonomy from their parent companies, and when intra-firm governance structures are less hierarchical, reverse knowledge transfers from subsidiaries to other firms within the MNC network can be significant (Cumings, Teng 2003). The acquisition of international technology is thus concerned with how MNCs successfully source, augment and increase their knowledge stock. We go one step further to determine not only the sources of knowledge spillovers internationally in the US, but the effect of such knowledge on the transfer of product design and R&D capability back to parent firms in Japan.

While Japanese MNCs are one of the most internationalized and innovative among industrialized countries (Porter, Sakakibara 2004), their investment to the US has been motivated by technological concerns: Japanese firms are attracted to US industries that are technology intensive (Kogut, Chang 1991; Jaffe, Trajtenberg 1998). A main reason for this is that international knowledge and technological spillovers from the US contribute significantly to firms' productivity in Japan (Todo, Shimizutani 2008). Compared to American and European firms, the international share of Japanese R&D is still quite low (Cantwell, Zhang 2006). But Japanese firms are also one of the largest R&D investors in the US, that is, they are well ahead of firms from Germany and the United Kingdom (National Science Board 2002). Our focus on Japanese subsidiary activities in the US should therefore shed light on the role of international spillovers on technology acquisition, and intra-firm knowledge transfers among MNCs.

In the next section, we elaborate upon the literature that provides the theoretical and behavioral contexts of firms in knowledge acquisition and intra-firm technology transfer. This is followed by a description of the survey data and methodology. Next, we analyze the data and discuss the results, and finally conclude with some implications of the findings.

## 2. International spillovers and intra-firm technology transfer: hypotheses

### 2.1. International spillovers

Firms have conventionally built their knowledge stock through developing internal R&D capability and upgrading their absorptive capacity (Cohen, Levinthal 1989). More recently, they have begun to augment their knowledge through international sources and spillovers. Shan and Song (1997) for example have argued that inward investment to the US is motivated by technology-specific assets. They show that foreign firms are drawn to US biotechnology companies' innovation and high level of patent activity. Similarly, both Iwasa and Odagiri (2004) and Song *et al*. (2011) have found that Japanese MNEs are establishing facilities in the US to access technological and knowledge spillovers. The hypotheses in this section are thus concerned with the relationship between spillovers sources and firms' level of knowledge acquisition.

The literature identifies basic and applied scientific research as well as product development to be the major types or modes of knowledge that are of interest to firms (Khoury, Pleggenkuhle-Miles 2011). Whereas basic science and research is aimed at advancing knowledge that may not be readily translated into tangible commercial ends, applied scientific research on the other hand, targets the building of knowledge and development of technical solutions that support product development. In turn, product development involves knowledge that underscores relevant tasks and functions with respect to its introduction to the market. Applied research and product development also differ in task characteristics requiring different sets of tools and methods (Nobelius 2004). Cumulative knowledge from all three modes increases a firm's capacity for future innovation, and therefore constitutes the dependent variables here. However, firms are also rarely able to pursue both basic and applied scientific research simultaneously because of prohibitive costs, and the greater uncertainty associated with basic scientific research (Arrow 1969; Henard, McFadyen 2005). This may explain why Japanese firms are much more oriented towards applied research and product development than basic scientific research (Song *et al.* 2011).

Because knowledge has a non-rival quality, it may be available to firms without incurring high additional costs. Knowledge produced in universities or research institutes for example may be useful to the needs of firms (Nelson 2011). Since university-generated knowledge is partly public, this results in horizontal spillovers to firms. Research institutes and universities serve two functions. They are sites of research and development (R&D); they also provide technical support and train workers. Bramswell and Wolfe (2008) observe that research institutes and universities are catalysts rather than drivers of innovation because their research contributes to a firm's stock of tacit knowledge.

The hiring of scientists and engineers from competitors forms another source of horizontal spillovers. Inter-firm labor mobility is a significant mechanism for knowledge spillovers and transmission (Fosfuri *et al*. 2001). According to Polanyi (1962), tacit knowledge is embodied in humans and not easily codified. Grossman and Helpman (1994) show that the human capital effect is not so much a function of labor size but the skills acquired by individuals to develop technology. Such skills include communication and collaborative skills. Hence Cummings and Teng (2003) maintain that scientists, engineers and technicians, and their social practices remain the single most important factor in the ability of a firm's mastery of product design, technology and knowledge. For this reason, we hypothesize that:

**H1a:** Research institutes, universities, and skilled labor positively influence the acquisition of knowledge.

Spillovers may also be vertical reflecting the relationship between suppliers and customers. Hippel (1988) and Baldwin *et al*. (2006) have shown that end user innovation occurs because customers find a new set of design or technology process possibilities. As lead users pursue these possibilities, manufacturers respond and begin to codify the product design. Consequently, end-users are typically involved in the development process because linking technological competence to customer knowledge is an integral part of product innovation (Su *et al*. 2006; Lee *et al.* 2011). We hypothesize that:

**H1b:** Customers positively influence the acquisition of knowledge.

Knowledge that enhances basic and applied research as well as product development may be codified, not just tacit (Nelson, Winter 1982). Because it is rarely completely tacit, some knowledge will need to be codified in order for scientists to communicate. The process of communication requires that generalizations and abstractions be standardized into a form that the scientific or professional community can appropriate and transmit to other units. Since codified knowledge is explicit and typically recorded, a good source lies in publications and blueprints (Thoenig, Vercher 2003). In this paper, we further include ISO certification. ISO 9000s for instance elaborates upon a quality system and acts as a codebook that describes the language, specifications and routines of a technical area. The process of certification requires a firm to demonstrate its procedures for process regulation as well as quality management, and to formalize such knowledge through codification (Benezech *et al*. 2001). Like tacit knowledge, spillovers from codified knowledge are expected to have a positive effect on knowledge acquisition. However, compared to tacit knowledge that tends to be more geographically localized (Audretsch, Feldmann 2004), codified information is more easily transmitted across distance. This means that Japanese parent firms should be able to access such knowledge from a distance reducing the need to establish subsidiaries in the US to exploit localized horizontal and vertical spillovers. Hence:

**H1c:** The effect of codified knowledge on knowledge acquisition may be positive or non-existent.

Finally, two other sources of spillovers also warrant investigation. They are professional conferences and seminars as well as alliance relationships. Because tacit knowledge tends to be human-embodied, seminars and conferences represent an organizational structure for scientists and engineers to share, transmit and accumulate knowledge. Hermann and Peine (2011) maintain that seminars and conferences increase interactions and contacts between scientists and expose firms to different ideas which is vital for the innovation process. Liberman and Wolf (1997) found that face-to-face social contacts enhance both the context and depth of knowledge being exchanged. Seminars and conferences help build knowledge networks among scientists, engineers and other skilled individuals. In addition to seminars and conferences, strategic alliance enables a firm to combine complementary technical know-how and skills with partners (Cummings, Teng 2003). Gils and Zwart (2004) suggest that firms create knowledge links while working with their partners. Such collaboration helps firms to learn, adapt and commercialize technology. The roles of seminars, conferences and strategic alliances imply that:

**H1d:** Seminars, conferences and strategic alliance positively influence the acquisition of knowledge.

## 2.2. Intra-firm technology transfer

When knowledge is sourced and acquired, it must be accompanied by intra-firm transfer for parent firms to benefit from the international activities of their subsidiaries. The second hypothesis and its subsets are concerned with the determinants of such transfers. Nobelius (2004) suggests that the frame of intra-firm transmission may be understood by examining the nature of transfer scope in product development. Typically, the product development process goes through several phases beginning with a planning phase to identify the requirements of the project. This is followed by concept design including costs, technical performance and attention to customer needs. At each phase, description of the product, that is, product design, and translation of information to performance characteristics are integrated with equipment design decisions since some materials may not be suitable or are too costly. Product development also involves the interaction of technical and operational choices. Pisano (1994) suggests that technical choices are an integral part of the firm's process technology. Hence product design is a central phase of the product development process because information gap from the market requires the firm to develop the appropriate design as well as technology for building successful prototypes. Through the product development process, firms learn to establish an optimal technological and production environment, integrate codified and tacit knowledge, establish organizational routines, and transform ideas into tangible products and innovation. All this implies that product design and R&D capability represent dimensions of technology that may be used to examine transfer scope. Nelson and Winter (2002) further make the point that product design undergoes a phase of experimentation during which product variety is high. Product design and R&D capability thus serve as the two dependent variables of interest for intra-firm transfers.

Once the product development process is approved and the product design is stable, the firm will turn to the applied research process to develop relevant technology solutions. Nobelius (2004) suggests that linking the two is vital. New product development is knowledge-intensive and cross-functional because it links the conceptualization of a product from R&D phase to manufacturing system design and operations. Its development requires detailed design, planning and testing. We expect that knowledge associated with new product development and applied research will enhance the transfer of product design and R&D capability to parent firms. On the other hand, because basic scientific knowledge is more abstract and reflects more fundamental and experimental knowledge, it should enhance R&D capability but may be less relevant to the transfer of product design.

**H2a:** Applied research and new product development positively influence intra-firm transfers.

**H2b:** Basic research is not expected to have any effect on intra-firm transfer of product design but should influence intra-firm transfer of R&D capability.

Firms will seek to internalize knowledge by establishing communication routines that capture intra-firm knowledge exchanges (Becker, Zirpoli 2008). Team collaboration aids the exchange of tacit knowledge and this requires face-to-face interactions (Teece 1996) and personal contacts (Arrow 1969). The governance structure of Japanese keiretsus has been linked to relatively high levels of inter-firm knowledge flows largely because of close contacts between suppliers and customers[1], as well as the circulation of management and exchange of personnel between different units of the organization. Such a structure enables keiretsus to compete because tacit knowledge among skilled individuals within the organization is difficult to replicate or imitate by competitors (Liker 2004). Communication routines are captured by scientific team visits between Japan and the US. We hypothesize that:

**H2c:** Scientific team visits from US subsidiaries to parent firms in Japan positively influence intra-firm transfers.

**H2d:** Scientific team visits from parent firms in Japan to US subsidiaries positively influence intra-firm transfers.

## 3. Variables and data

### 3.1. Variable operationalization

#### International spillovers

*Dependent variables*. Sections 2.1 and 2.2 identify three dependent variables capturing knowledge modes for H1a, H1b, H1c and H1d. For knowledge modes, we asked firms to rank the significance of their acquisition of basic scientific research, applied research and new product development after establishing their units in the US. The ranking is based on a likert scale of 1 (not significant at all) to 7 (very significant). Firms that ranked the three knowledge modes 4.0 or greater are treated as acquiring significant knowledge of the corresponding mode (Table 1).

[1] Ok (2011) also found the level of customer-supplier interactions to be important among Dutch companies.

*Independent variables*. The independent variables of interest for the hypotheses are:

(i) R&D personnel. This is a binary variable where 1 denotes that the share of skilled R&D personnel is above 5%, and 0 otherwise.

(ii) Research institutes and universities, customers, publications and industry certification, and strategic alliance. For these variables, firms were asked to assess their importance in their ability to acquire new knowledge based on a likert scale of 1 to 7 (1=very unimportant, 7=very important).

**Table 1.** Variables and measurement

| Variables | Survey question and measurement | Measurement in the regressions |
|---|---|---|
| Dependent variable: | | |
| A. Knowledge mode<br>i. Basic science<br>ii. Applied science<br>iii. New product development | Please estimate if acquisition of the following mode of knowledge has been significant after establishing your firm in the US (1= not significant at all, 7 = very significant) | Dummy variable = 1 if ranked 4 or greater = 0 otherwise |
| B. Intra-firm transfer<br>i. Product design<br>ii. R&D capability | Since your firm was established, do you agree that it has transferred the following technology to parent companies? (1 = strongly disagree, 7 = strongly agree) | Dummy variable = 1 if ranked 4 or greater = 0 otherwise |
| Independent variable: | | |
| C. Spillovers<br>i. R&D personnel | Share of R&D personnel in total employment (%) | Dummy variable = 1 if above 5% = 0 otherwise |
| ii. Customers located within 300 miles<br>iii. Participation in seminars & symposiums<br>iv. Publications, blueprints & industry certification<br>v. Research institutes and universities | How important are the following factors in acquiring or developing new knowledge and technology in your firm? (1 = not significant at all, 7 = very significant) | Ordinal data 1–7 |
| D. Communication variables<br>i. US-based scientists and engineers to Japanese facilities<br>ii. Japanese scientists and engineers to US-based facilities | Have the following practices increased since this company was established in the US? (1 = did not increase at all, 7 = increased very significantly) | Ordinal data 1–7 |

### Intra-firm technology transfer

*Dependent variables*. In order to determine the scope of technology transfer, we asked firms if they agreed that they had transferred knowledge and technology to their parent companies in Japan (1 = strongly disagree, 7 = strongly agree). Two aspects of the transfer scope are identified, namely, product design and R&D capability. Firms that rank the two dimensions of transfer scope 4.0 or above are said to experience significant intra-firm transfer.

*Independent variables*. In addition to the three knowledge modes described above, we are interested in the effect of communication routines on intra-firm transfers. Two independent variables are used to measure this: firms were asked if visits from (a) their US scientific teams to parent firms, and (b) Japanese scientific teams to the US had increased since establishing their facilities there.

### Control variables

The literature has also identified a number of other influences that will serve as control variables in this paper. They are:

(i) Sector. Some manufacturing industries such as pharmaceuticals, biotechnology, transport equipment, electronics and electrical goods are more innovation-oriented (Henard, McFadyen 2005). Two binary variables measuring the high tech sector and transportation sector respectively are therefore included in the regressions. The other industries including machinery and parts and primary, non-ferrous, fabricated metal are the omitted category in the regression.

(ii) Market power. Peeters and van Pottelsberghe de la Potterie (2006) found that firms that are larger tend to have more market power. In turn such firms are also engaged in higher levels of innovation. Market power is expressed as a dummy variable indicating the total annual worldwide sales of the US-based firm above $50 million. In the sample, over 55% of firms report annual sales greater than $50 million.

(iii) R&D intensity. As pointed out earlier, firms invest in internal R&D capability to increase their absorptive capacity (Cohen, Levinthal 1989). The intensity of R&D expenditure contributes to the building of such capability that in turn results in flows of new knowledge (Deeds 2001; Teece 1996). Seventy-two percent of the firms indicated that R&D intensity, measured as share of R&D expenditure, is at least 5% of their total expenditure

(iv) Mode of entry. Outward direct investment is said to facilitate international sourcing (Blomstrom, Kokko 2003; Weng *et al.* 2010). However knowledge may also be acquired through other modes of entry such as mergers and acquisition (M&A) and strategic alliance (Cummings, Teng 2003; Ginevičius 2010). The mode of entry in the regression is a binary variable where mode of entry equals one if the US subsidiary was established through direct investment and zero if it was formed through strategic alliance or M&A. Seventy percent of the firms were established through direct investment.

(v) Subsidiary autonomy. The management literature has argued that for subsidiaries to innovate, they need to be relatively independent from their parent companies. This increases their embeddedness in the host environment and enhances opportunities to exploit and assimilate new knowledge (Phene, Almeida 2008). Japanese subsidiaries were asked to rank from 1 to 7 if their autonomy in the following two areas had increased since establishing their facilities in the US: (a) financial budgets and expenditures, and (b) R&D.

(vi) Governance mode. The governance structure of Japanese keiretus is well known for encouraging high levels of inter-firm knowledge flows (Muffatto 1998). Here, we asked firms to indicate if they are part of a keiretsu network. In the sample, 51.4% of the firms reported that they were part of a keiretu.

### 3.2. Survey data

Based on the *2002 Directory of Japanese Affiliated Companies in the US and Canada*, a questionnaire was mailed to 800 Japanese manufacturing companies in the US in 2005[2]. Within a month, a total of 140 questionnaires were received. Thirty-two of the questionnaires could not be used because the addresses did not exist, the firm was no longer in operation, or the firm was not a Japanese subsidiary. This is consistent with our experience elsewhere in using directories listing Asian firms where information tends not to be up-to-date. This leaves 108 usable questionnaires. At the end of six weeks, a second mailing was sent to the firms again that had not responded. This time, the number of erroneous addresses was much lower leaving us with 77 usable instruments. The total number of surveys that may be used for this paper is therefore 185[3]. This represents a response rate of about 23%. However given that 22% of the returned surveys were unusable, the population is likely to be much smaller than the original population of 800. This implies that the response rate is much higher and closer to 30% or more which is considered to be a good response rate (Harzing 1997).

Since mail surveys can result in unit non-response, we tested for such potential bias using the method proposed by Armstrong and Overton (1977). We tested for market power ($p = 0.43$), entry mode ($p = 0.41$), if the firm is part of a keiretsu ($p = 0.39$), and share of R&D personnel ($p = 0.30$) between early and late respondents. T-tests of all the dependent variables used in section 4.0 also show no significant differences (see Appendix 1). However, early respondents show a higher number of firms in the high tech sector. Baker *et al.* (1985) suggest that conducting a second mailing helps to reduce non-response bias. This was done here: the second mailing has a much lower number

[2] While the survey was conducted in 2005, the entire data collection ended in February 2006. That the data is five years old should not affect the findings in section 4.0. Evolutionary theory suggests that organizational change is slow (Nelson, Winter 1982). For example, our survey shows that the transfer and circulation of workers among Japanese firms continue to be important in 2005. This is consistent with Kenney and Florida's (1994) conclusion more than a decade ago.

[3] Because of missing values for some variables, the number of observations in the following regressions, which is reported in the tables, is smaller than 185.

of high tech firms and this helps adjust for over-sampling in the first mailing. In the analysis below, we also control for sector to eliminate any possible estimation bias due to response bias in sector.

Because the *2002 Directory of Japanese Affiliated Companies in the US and Canada* provides information on age of firms, we further compared our sample to the population data for possible bias. The t-tests show that there is no significant difference in age ($p = 0.68$).

## 4. Results and findings

As outlined earlier, two interrelated questions and their hypotheses will be examined in this section. The first is concerned with the sources of international spillovers that influence knowledge mode acquisition among Japanese firms. The second will investigate if major knowledge modes have influenced the technological dimensions of transfer scope from subsidiaries to parent companies in Japan.

### 4.1. International spillovers and knowledge acquisition

Sixty and thirty-six percents of the Japanese firms reported significant acquisition of knowledge in product development and in applied research respectively. The figure is much lower for basic science, that is, 22%. This is consistent with the literature reviewed earlier that research associated with basic science is much more uncertain and costly to invest. Hence fewer firms are likely to invest in facilities for basic scientific research.

Table 2 provides summary statistics for the independent variables. To assess the influence of knowledge spillovers, firms were asked to provide the share of skilled R&D personnel. Thirty-one percent of the firms reported a share of over 5% though this varies across the three knowledge modes. Firms that reported significant acquisition of knowledge for basic science also had the highest share at 45%. This is followed by firms with significant acquisition in applied research (40%) and new product development (34%). For the other variables, the table presents two variations of the survey output. The first column presents the means of the ranking for each source of all firms whereas means in the second, third and fourth columns are associated with firms that report significant knowledge acquisition in basic science, applied research and product development. The table reveals that for basic science and applied research (columns 2 and 3), firms that are engaged in significant knowledge sourcing rank tacit knowledge factors like strategic alliance and R&D institutions and universities above 4.0. For codified knowledge in publications, blueprints and industry certification, the means are close to 4.0. Surprisingly, customers are ranked between 2.3 to 2.7. This may be because the survey restricted customers to those that are located within 300 miles on the rationale that geographical proximity enhances personal contacts and networks between the firms and their customers (see Phene, Almeida 2008). Nonetheless, Table 2 indicates that both codified and tacit knowledge are being sourced and acquired by Japanese firms.

**Table 2.** International Knowledge Spillovers*: summary statistics

| Spillovers | All firms | Firms with significant acquisition in basic science | Firms with significant acquisition in applied research | Firms with significant acquisition in product development |
|---|---|---|---|---|
| Skilled R&D personnel (>5%) | 0.23 | 0.45 | 0.40 | 0.34 |
| Research institutes & universities | 3.41 | 4.38 | 4.12 | 3.94 |
| Customers | 2.46 | 2.59 | 2.29 | 2.66 |
| Strategic alliance | 3.20 | 4.34 | 4.04 | 3.66 |
| Seminars & conferences | 3.20 | 3.59 | 3.65 | 3.42 |
| Publications & industry certification | 3.98 | 3.91 | 3.86 | 4.07 |

* All variables except above 5% skilled R&D personnel are based on likert scale 1 = not important at all, 7 = very important

Probit regressions were run to estimate how the above sources of spillovers affect the propensity of firms to report significant development in the three modes of knowledge (that is basic science, applied scientific research and product development). The probit model is of the following form:

$$y_{im}^{*} = \beta_0 + X_{1i}\beta_1 + X_{2i}\beta_2 + \varepsilon_i , \quad (1)$$

where $y_{im}^{*}$ is a latent variable, denoting a measure of strength for firm *i* in knowledge acquisition of knowledge mode *m*. If $y_{im}^{*} > 0$, firm *i* acquires significant knowledge of mode *m*, that is $y_{im} = 1$, else $y_{im} = 0$. As mentioned above, the degree of knowledge acquisition with a rank of 4 or above is defined as significant, and the three modes of knowledge are basic scientific research, applied research and product development; $X_{1i}$ and $X_{2i}$ are vectors of knowledge sources and control variables respectively. The error term, $\varepsilon_i$, is assumed to follow standard normal distribution[4].

Table 3 reports the results of the probit regressions. Two models for each knowledge mode are presented: the first uses financial autonomy while the second, R&D autonomy to measure the subsidiary's independence from its parent company. All six regressions indicate that only the share of R&D personnel and market power are consistent predictors of significant development for all three knowledge modes. That is to say, firms with a higher share of skilled R&D personnel and greater market power are more likely to experience significant knowledge acquisition in basic and applied scientific research as well as product development. The former highlights the role of tacit knowledge embodied in individuals who are engaged in innovation.

[4] We also ran the data using logistic regressions and found the results to be relatively similar. The logistic estimates are available from the authors upon request.

Tacit knowledge from customers has a positive effect on basic science and product development although the significance levels vary from marginal (10%) to high (1%). While customers may be ranked relatively low in Table 2, knowledge acquired from customers remains relevant for the firm that desires to augment its technological competency in basic science and product development. Innovation is a market-driven endeavor and customers are key to ensuring that product development remains commercially feasible (Su *et al*. 2006). In addition, since many of the customers in the survey represent downstream demand in the value chain, their inputs have contributed positively to firms' basic scientific knowledge perhaps because a combination of fundamental knowledge and commercial end is more desirable among Japanese subsidiaries. Research institutes and universities are positive and significant in the acquisition of basic scientific knowledge. This is consistent with the literature that finds university-industry linkages to be an important mechanism driving innovation (Anselin *et al*. 1997). Interestingly, participation in seminars and conferences is positive and significant for applied research. Herrmann and Peine (2011) maintain that seminars and symposiums are a source of ideas, and participation in seminars encourages contact and interactions with experts on the latest technology and applications. This channel of knowledge acquisition would appear to be effective for Japanese firms since they are much more focused on applied research than basic science.

Firms that rely on codified knowledge through publications, blueprints and industry certification are unlikely to acquire any significant knowledge given that this factor is not significant for any of the three knowledge modes. The finding makes intuitive sense given that basic scientific research is typically initiated to broaden a firm's stored knowledge, and to enhance its future applied research performance. Publications, blueprints and industry certification tend to offer more duplicative knowledge because knowledge associated with it may be public and available to competitors (Henard, McFadyen 2005; Nelson 2009). In addition, many of the firms surveyed were sourcing information from manuals rather than scientific publications; hence any new knowledge acquired from this source is unlikely to be substantial. Because the control variable entry mode includes strategic alliance with another company in the US, we did not include strategic alliance as an external source in the regressions. Table 3 further suggests that subsidiary autonomy both in the context of financial budgets and expenditures as well as R&D autonomy contributes to the acquisition of knowledge in all three modes. The findings would seem to support the literature that when parent companies exert a lower control of their subsidiaries, the latter is given greater freedom to scout for knowledge that contributes to knowledge acquisition.

The pseudo r-squareds vary from 0.25 to 0.28. They are slightly higher for knowledge acquisition in applied science and product development when R&D autonomy is used instead of financial autonomy. The standard errors are also generally higher for knowledge acquisition in basic science and this suggests a larger variance among firms that are associated with this knowledge mode.

Overall, the regression results support H1a, H1b and H1d, but not H1c. This is generally consistent with the findings of Kurokawa *et al*. (2007) and Song *et al.* (2011).

Kurokawa and his colleagues found that market-related factors contribute to knowledge flows in their survey of 85 Japanese firms with global R&D. This indicates that customers are a principle source of innovation. Contrary to this study, they hypothesized that subsidiary autonomy would lower vertical spillovers because of the lack of control by parent companies over them. Their findings however did not support such a hypothesis implying that subsidiary autonomy does positively affect vertical knowledge flows to parent firms. Our results are much more consistent with the latter finding and with Song *et al*. (2011) who also conclude that subsidiary autonomy is important for exploiting knowledge spillovers in the US.

Finally, it is noteworthy that when R&D autonomy is introduced into the regression, the effects of other external sources are reduced. One possible explanation is that a high level of financial autonomy does not directly translate into weak parent control compared to R&D autonomy. The subsidiaries may simply be given a greater amount of discretionary in decisions concerning expenditures in finance but may still be dependent on parent firms for technology. On the other hand, subsidiaries that are given considerable R&D autonomy are often able to pursue independent technological trajectories by becoming embedded in innovative host environments. In this case, building internal subsidiary capability in product development is focused on having the right skilled personnel, and those with greater market power are more likely to have the ability to do this. However, the question remains if the scouting and subsequent acquisition of the three modes of knowledge are being transferred to parent firms.

**Table 3.** Probit regressions: International spillovers and knowledge acquisition

| Variables | Basic science | | Applied science and research | | Product development | |
|---|---|---|---|---|---|---|
| Spillovers: | | | | | | |
| Skilled R&D Personnel | 0.864** | 0.802** | 0.812** | 0.721* | 1.100*** | 0.981** |
| | (0.405) | (0.396) | (0.371) | (0.371) | (0.396) | (0.403) |
| Research institutes & Universities | 0.182** | 0.112 | 0.059 | –0.013 | 0.100 | 0.036 |
| | (0.092) | (0.096) | (0.080) | (0.087) | (0.074) | (0.080) |
| Customers | 0.146* | 0.129 | 0.020 | 0.005 | 0.141** | 0.130* |
| | (0.080) | (0.079) | (0.074) | (0.075) | (0.068) | (0.070) |
| Seminar & conferences | 0.040 | –0.012 | 0.235** | 0.206* | 0.082 | 0.043 |
| | (0.126) | (0.126) | (0.115) | (0.115) | (0.103) | (0.103) |
| Publications & industry certification | –0.155 | –0.116 | –0.170 | –0.133 | 0.005 | 0.039 |
| | (0.119) | (0.118) | (0.105) | (0.106) | (0.092) | (0.094) |
| Control variables: | | | | | | |
| R&D intensity | 0.567 | 0.157 | 0.542 | 0.146 | 0.200 | –0.176 |
| | (0.472) | (0.477) | (0.375) | (0.392) | (0.303) | (0.326) |

*Continued Table 3*

| Variables | Basic science | | Applied science and research | | Product development | |
|---|---|---|---|---|---|---|
| Financial autonomy | 0.215** | | 0.163** | | 0.164** | |
| | (0.091) | | (0.076) | | (0.068) | |
| R&D autonomy | | 0.218** | | 0.240*** | | 0.254*** |
| | | (0.095) | | (0.089) | | (0.087) |
| High tech | 0.304 | 0.292 | 0.336 | 0.367 | 0.704** | 0.727** |
| | (0.374) | (0.369) | (0.340) | (0.343) | (0.323) | (0.327) |
| Transportation | –0.620 | –0.596 | –0.499 | –0.470 | –0.269 | –0.250 |
| | (0.422) | (0.419) | (0.351) | (0.355) | (0.311) | (0.317) |
| Market power | 1.045*** | 1.101*** | 1.008*** | 1.116*** | 0.638** | 0.711** |
| | (0.373) | (0.376) | (0.328) | (0.339) | (0.275) | (0.281) |
| Entry mode | –0.040 | 0.042 | –0.345 | –0.272 | –0.141 | –0.084 |
| | (0.335) | (0.341) | (0.292) | (0.299) | (0.270) | (0.273) |
| Keiretsu | 0.004 | 0.004 | –0.301 | –0.287 | –0.273 | –0.240 |
| | (0.313) | (0.309) | (0.281) | (0.281) | (0.262) | (0.265) |
| Observations | 132 | 132 | 131 | 131 | 138 | 138 |
| Pseudo $R^2$ | 0.281 | 0.276 | 0.266 | 0.282 | 0.250 | 0.265 |

**Notes:** Standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

### 4.2. Intra-firm transfers

The previous section indicates that exploiting international tacit knowledge spillovers have contributed to Japanese subsidiaries' acquisition of knowledge in basic and applied scientific research as well as product development. This section aims to find out if the acquired knowledge has been transferred to parent companies and the factors that determine successful intra-firm transfer. This question is relevant because such transfers are a major motivation for the international sourcing of knowledge as they help to augment parent firms' technological assets.

As described in section 2, product design is a principal phase of the product development process. Product design is key to product development because it enables the firm to take the product from idea phase to release on the market. Developing this area of technological capability demands purposeful exploitation of knowledge gained through basic and applied scientific research. On the other hand, R&D capability is conventionally developed in parent companies first and then transferred to subsidiaries. But as Shan and Song (1997) have shown in the biotechnology industry, scientific breakthroughs in the US will mean that such capability is being reverse transferred by subsidiaries established in the US instead.

Table 4 presents the t-test results of the scope of intra-firm knowledge transfer for subsidiaries that are engaged in significant levels of basic and applied scientific research and product development (that is, with ranking of 4 or above). Firms are separated into two groups according to the degree of knowledge acquisition in each of the three knowledge modes. The first group consists of firms that ranked the variables 1 to 3, while firms in the second group ranked them 4 or above. This means that group 2 is significantly involved in knowledge acquisition but not group 1. The figures in table 4 refer to the share of firms in each group that ranked intra-firm transfer for product design and R&D capability above 4. For example, 21% of firms in group 1 who are engaged in negligible basic science acquisition indicate that they have significantly transferred technology in product design to their parent companies. On the other hand, thirty-six percent of firms in group 2 who are engaged in significant basic science acquisition are involved in such transfers, and the p-value further shows that group 2's share is significantly higher. Indeed this is true for all three modes of knowledge: Japanese subsidiaries that are significantly acquiring new knowledge in basic science, applied research and product development in groups 2 are also more likely to transfer technology in product design and R&D capability to their parent firms.

**Table 4.** T-tests of intra-firm transfers

| Knowledge mode | Product design | R&D capability |
|---|---|---|
| Basic Science | | |
| Group 1 | 0.21 | 0.21 |
| Group 2 | 0.36 | 0.48 |
| P-value | 0.06 | 0.00 |
| Applied science | | |
| Group 1 | 0.19 | 0.15 |
| Group 2 | 0.35 | 0.50 |
| P-value | 0.02 | 0.00 |
| Product development | | |
| Group 1 | 0.12 | 0.11 |
| Group 2 | 0.36 | 0.40 |
| P-value | 0.00 | 0.00 |

Besides knowledge modes, we also examine if the communication routine and flows that the firms have established facilitate intra-firm transfer. Cummings and Teng (2003) suggest that knowledge transfer depends on what they call "norm distance". By this, they mean that teams of skilled workers should share similar cognitive and social practices that close the skill gap between individuals. Closing this gap is more likely to result in successful knowledge transfer. Clearly the nature of norm distance depends on the firm's communication structure because teams that share similar communication and cultural values are more likely to articulate, receive and process information more efficiently. Communication flows are enhanced when scientists and engineers share similar norms of doing science and research. Japanese firms for instance are found to excel in organizational practices that promote knowledge creation and transfer (Ueki *et al*. 2011).

Communication routines are measure in terms of team exchanges (see section 3.2). Such exchanges facilitate direct communication and thereby knowledge flows, and are expected to be a major mechanism by which intra-firm knowledge is transmitted. Summary statistics indicate that team visits increased significantly with the establishment of subsidiaries in the US: firms report means of 4.4 to 4.8 for increase in "visits of scientists and engineers from the US to Japan". Similarly, they rank increase in "visits of scientists and engineers from Japan to the US" between 4.5 and 5.0.

We use probit regressions to estimate if knowledge acquired and communication routines are likely to increase the propensity of firms to engage in significant intra-firm technology transfer to their parent companies in Japan. These are supplemented by two control variables, that is, sector and governance mode which the literature have identified as being relevant (Cummings, Teng 2003; Giroud 2000). Studies suggest that the organizational practices of keiretsus encourage strong intra-firm and inter-firm collaborations and networking (Muffatto 1998), hence we expect that knowledge transfer is facilitated when the subsidiary is part of a keiretsu.

Two models for each transfer scope are presented in Table 5. Columns 1 and 3 in the first model do not contain any control variable while they are added in the second model (columns 2 and 4). Both models show that firms that are more successful in acquiring product development knowledge are more likely to transfer both product design and R&D capability to parent firms. This is consistent with expectations because product design needs to be in place to support product development and its innovation. It enables a firm to exploit economies of scale and scope, and enhance learning through route and tacit knowledge acquired over time (Brown 2001). The results indicate that product development is necessary to develop dynamic R&D capability because this helps shape firms' internal and external competency. They also show that subsidiary knowledge in applied science helps to strengthen dynamic capability among parent firms through intra-firm transfers. Teece (1977) notes that applied scientific research enhances the capability of a firm to manufacture not only a product, but also a process. Hence, applied research directly augments parent firms' technological assets by increasing its capability in R&D. Knowledge from basic science on the other hand has no effect on any intra-firm transfer but may be explained by its more experimental nature. Research in basic science is predominantly directed at producing a broader base of knowledge that might solve some technical problem in the future. The uncertain characteristics of this mode of knowledge may explain why the latter has not directly contributed to technology transfer. The pseudo r-squareds increase slightly when we include the control variables.

Interestingly, teams visits of scientists and engineers from US to Japan have a positive effect on the transfer of R&D capability while the opposite is true for team visits from Japan to the US. This is interesting because it implies that more sophisticated technological capability is being transferred by skilled personnel from subsidiaries to parent companies. In contrast, parent companies may be sending their teams from Japan to ensure quality control or to adapt innovations originating from Japan to US markets. Our results echo Song *et al.*'s findings (2011). They show that tight control of subsidiaries by parent firms prevents subsidiaries from developing knowledge that directly benefits parent firms. The results suggest that technology transfer is a process that involves substantial communication and coordination between personnel. Having such team exchanges from the US achieves two ends. First it helps overcome the geographical barrier of distance between Japan and the US. Second, since the teams are assembled by the subsidiary, they tend to share similar organizational norms and cognitive models. All this increases the effectiveness of the scope of technology transfer.

Finally, Table 5 also reveals that transfer of product design is positively associated with firms in the high-tech but not in the transportation sector. One explanation is that parent firms in the transport sector such as the automobile industry are already highly innovative and subsidiary R&D knowledge plays a relatively minor role. Much of the literature about this sector, for instance, points to the transfer of knowledge from Japan to the US rather than the reverse (Pudelko, Mendenhall 2009). While the keiretsu governance mode is said to facilitate knowledge flows, we found that governance mode has no effect on intra-firm transfers.

**Table 5.** Probit regressions: Intra-firm subsidiary to parent transfers

| | Product design | | R&D capability | |
|---|---|---|---|---|
| Basic science | 0.132 | 0.144 | –0.030 | –0.012 |
| | (0.109) | (0.116) | (0.110) | (0.115) |
| Applied science | –0.107 | –0.152 | 0.303*** | 0.260** |
| | (0.116) | (0.124) | (0.117) | (0.121) |
| Product development | 0.231*** | 0.197** | 0.195** | 0.176** |
| | (0.081) | (0.084) | (0.083) | (0.085) |
| Team visits from US to Japan | 0.006 | 0.020 | 0.229** | 0.192* |
| | (0.103) | (0.108) | (0.106) | (0.113) |
| Team visits from Japan to US | 0.119 | 0.179 | –0.227** | –0.177 |
| | (0.098) | (0.109) | (0.101) | (0.110) |
| High tech | | 0.482* | | 0.275 |
| | | (0.291) | | (0.295) |
| Transportation | | 0.027 | | –0.604 |
| | | (0.315) | | (0.371) |
| Keiretsu | | –0.403 | | –0.173 |
| | | (0.254) | | (0.270) |
| Observations | 151 | 145 | 151 | 145 |
| Pseudo $R^2$ | 0.102 | 0.134 | 0.249 | 0.270 |

**Notes:** Standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

In sum, the findings in this section provide support for H2a and H2c. The effect of basic science on intra-firm transfer is much less straightforward. While some support may be found for H2b in that basic science has no effect on product design, its insignificant effect on R&D capability is unexpected. It would appear that the more fundamental nature of basic scientific knowledge is difficult to much more difficult to transmit than either applied research or product development. Interestingly, support may be found for H2c but not H2d. This would seem intuitive from the viewpoint that knowledge transmission from skilled personnel in US-based subsidiaries is more effective in reverse intra-firm flows since it is engaged with new knowledge from the US. Furthermore, the pseudo r-squareds are higher for intra-firm transfers in R&D capability (0.25 to 0.27) compared to transfers associated with product design (0.10 and 0.13).

## 5. Discussion and conclusion

The acquisition of knowledge and the scope of technology transfer to parent companies underscore the major themes of this paper. Managing, acquiring and transmitting knowledge from innovation-rich environments like the US back to home countries have become an important aspect of international R&D sourcing strategies. Reverse intra-firm subsidiary to parent knowledge flows in turn enable Japanese multinationals to build competitive advantage as technology becomes a key asset to firms.

The aforementioned themes were examined through probit regressions that attempt to explain first, relevant sources of knowledge spillovers that contribute to firms' technology acquisition, and second, if knowledge modes acquired positively influence intra-firm transfers. Knowledge modes are captured as basic, applied scientific and product development knowledge. The regression results reveal that R&D personnel and market power have a consistent influence in the acquisition of all three knowledge modes. Tacit knowledge in individuals, which is distinguished from codified knowledge by its disembodied nature, rootedness in social practices and experience, and resistance to easy transmission across space, thus plays an effective role on Japanese subsidiaries' acquisition behavior. A higher share of R&D personnel enables firms to assimilate new knowledge, and firms that possess greater market power are also more likely to have the resources to manage knowledge assimilation. Disembodied knowledge acquisition involves the take-up of learned behavior in a social context; hence it may also be sourced from customers, research institutes or universities. These sources are most relevant to the acquisition of basic scientific knowledge. Not surprising, customers are also central to firms' acquisition of product development knowledge. On the other hand, learning through seminars and symposiums is more effective for acquiring applied scientific knowledge. Interestingly, codified knowledge through publications and industry certification has no effect at all. This suggests that explicit knowledge does not add to firms' stock of fundamental knowledge perhaps because such codified knowledge is not central to the firm's core competency.

We ran probit regressions to analyze if the above three knowledge modes have influenced intra-firm subsidiary to parent transfers of product design and R&D capability.

The former expresses the tangible scope of technology transfer while R&D capability is expected to enhance parent firms' absorptive capacity and thereby competitive advantage. The results indicate that subsidiaries' acquisition of product development knowledge significantly influences the transmission of product design and R&D capability to parent companies. Applied research facilitates intra-firm transfers of R&D capability. Basic scientific knowledge does not have any effect at all. It appears that while basic science may help to enhance a subsidiary's knowledge base, its more uncertain nature also deters vertical transmission. Moreover, organizational capacity that facilitates the sharing of knowledge may be lacking: firms must establish routines that ease the transportability of knowledge. Such transfer mechanisms may be harder to establish in basic scientific knowledge. Communication routine and flows in the form of team visits from the US indicate that knowledge in R&D capability is much more readily transmitted when such procedures are in place given the relevance of social and cognitive contexts in knowledge flows.

In sum, we have identified the sources of influence on Japanese subsidiaries' acquisition of various knowledge modes, and the role that these modes play in intra-firm technology transfer. The effect of international knowledge sourcing on the competitive advantage of firms, however, remains an empirical question. This is beyond the scope of the paper but constitutes an important direction for future research.

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# APPENDIX 1

## Sample bias tests

| Unit non-response | | | |
|---|---|---|---|
| | Early respondents | Late respondents | P value |
| Market power | 0.523 | 0.583 | 0.426 |
| Entry mode | 0.655 | 0.712 | 0.411 |
| Keiretsu | 0.519 | 0.586 | 0.385 |
| Skilled R&D Personnel | 0.253 | 0.185 | 0.301 |
| High tech | 0.358 | 0.203 | 0.020 |
| Transportation | 0.275 | 0.257 | 0.783 |
| Basic science | 2.585 | 2.279 | 0.248 |
| Applied science | 3.076 | 2.705 | 0.199 |
| Product development | 3.959 | 3.857 | 0.736 |
| Product design | 2.676 | 2.559 | 0.660 |
| R&D capability | 2.663 | 2.602 | 0.995 |
| Difference between population and sample | | | |
| | population | sample | |
| age | 18.063 | 17.672 | 0.676 |

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