The Location of Multinational firms' R&D Activities abroad: Host Country University Research and R&D Heterogeneity

Citation for published version (APA):

Suzuki, S., Belderbos, R., & Kwon, H. U. (2017). The Location of Multinational firms' R&D Activities abroad: Host Country University Research and R&D Heterogeneity. In J. Alcacer, B. Kogut, C. Thomas, & B. Y. Yeung (Eds.), *Geography, Location, and Strategy* (pp. 125-159). Emerald Group Publishing Limited. Advances in Strategic Management Vol. 36 <https://doi.org/10.1108/S0742-332220170000036005>

Document status and date:

Published: 01/01/2017

DOI:

[10.1108/S0742-332220170000036005](https://doi.org/10.1108/S0742-332220170000036005)

Document Version:

Other version

Document license:

Taverne

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.umlib.nl/taverne-license

Take down policy

If you believe that this document breaches copyright please contact us at:

repository@maastrichtuniversity.nl

providing details and we will investigate your claim.

Download date: 26 Apr. 2023

The Location of Multinational firms' R&D Activities abroad: Host Country University Research, University-Industry Collaboration, and R&D Heterogeneity

Shinya Suzuki

Musashi University and NISTEP

Rene Belderbos

KU Leuven, UNU-MERIT, and Maastricht University

Hyeog Ug Kwon

Nihon University and RIETI

Published as:

Suzuki, S., Belderbos, R., and Kwon, H.U.(2017), "The Location of Multinational Firms' R&D Activities Abroad: Host Country University Research, University–Industry Collaboration, and R&D Heterogeneity", *Geography, Location, and Strategy (Advances in Strategic Management, Vol. 36)*, Emerald Publishing Limited, Bingley, pp. 125-159

ABSTRACT

We examine the determinants of multinational firms' propensity to conduct R&D activities in host countries, with specific attention to the influence of host countries' university research. We consider heterogeneous locational drivers related to the type of R&D activity: basic research, applied research, development for local markets, and development for global markets. Drawing on official survey data on R&D activities by 498 Japanese multinational firms in 24 host countries and estimating two-stage models, we find that the likelihood that firms conduct R&D in a host country is generally increasing in the strength of university research. Conditional on a firm's R&D presence, university research strength is associated with a greater propensity to conduct (basic) research activities rather than (local) development, while the intensity of host country university-industry collaboration is most strongly associated with applied research. Host country experience and the depth of the firm's manufacturing presence are also associated higher propensities to engage in research.

INTRODUCTION

Extant literature has suggested an increasing importance of international R&D by multinational firms (UNCTAD, 2005; OECD, 2011; Moncada-Paterno-Castello et al. 2011). This trend has been associated with a more pronounced role of foreign R&D as a vehicle to access overseas technological expertise and to create new technologies, rather than its traditional role of adaptation of existing technologies to foreign markets (Kuemmerle, 1997, Chung and Yeaple, 2008). As the importance of technology-sourcing motivated R&D increases, university research in host countries is receiving more attention as a potential attractor of foreign R&D, since knowledge spillovers from, and collaborative research with, academia can play a critical role in the creation of new technologies (Alcacer and Chung, 2007; Hegde and Hicks, 2008, Anselin et al., 1997). However, with some exceptions (Cantwell and Piscitello, 2005; Belderbos et al., 2014), the role of (collaborative) university research in attracting R&D investments by multinational firms has received surprisingly little attention.

Prior research has rarely been able to take into account that R&D can consist of a variety of activities: basic research, applied research, and product development, with the latter focused on local or global markets. Each of these activities is likely to be associated with different locational drivers (e.g. Kuemmerle, 1997; Belderbos et al., 2009; von Zedtwitz and Gassmann, 2002). Development activities are more geared towards adapting products and processes to foreign demand, while research activities benefit from local technological opportunities and proximity to R&D clusters (Shimizutani and Todo, 2008; Iwasa and Odagiri, 2004; Kuemmerle, 2009). A very much open question is to what extent such heterogeneity in responsiveness arises with respect to the strength and nature of host country university research.

In this paper, we examine these underexposed issues by contributing a study of the determinants of Japanese multinational firms' R&D activities across their host countries. A unique characteristic of our data is that we can distinguish whether host country R&D activities involve basic research, applied research, development for local markets, and/or development for global markets. Specifically, we utilize a dataset of 498 Japanese multinational firms' activities in 24 host countries in 1996. We examine to what extent the strengths of university research and the intensity of host country university-industry collaboration are associated with higher propensities of Japanese firms to conduct R&D in host countries, and, more specifically, which types of R&D. We draw on micro data on scientific publications by academic field and author locations drawn from Thomson Reuters' Web of Science database to derive measures of relevant university strength and collaboration by host country and industry. In addition to university research, we examine the role of market and cost factors, the strength of intellectual property rights protection, host country experience, and the extent to which firms are active in other value chain activities in the host country.

Japanese MNCs are an interesting case to examine. A relative latecomers in the internationalization of R&D, the scale of their R&D operations abroad has been smaller than that of their US and European counterparts (Belderbos, 2003; 2001; Kuemmerle, 1999). This has been related to a specific organization of R&D focusing on design for manufacturability, speed of new product introduction, and continuous process improvements, which rely on intensive coordination and communication between headquarters, R&D, marketing, and manufacturing functions, as well as collaboration with suppliers (Kenney and Florida, 1994; Westney, 1994). Such an organization favors a relatively strong geographical concentration of

manufacturing, applied R&D, and engineering facilities near headquarters in Japan, while this system of R&D integration is more difficult to transfer abroad over long distances and cultural and language barriers (Belderbos, 2001). At the same time, prior research has suggested that foreign R&D by Japanese firms, like foreign R&D by US and EU firms, involves technology sourcing motivation (e.g. Penner Hahn and Shaver, 2005; Song, Asakawa and Chu, 2011; Iwasa and Odagiri, 2004; Shimizutani and Todo, 2008) with effective knowledge transfer back to Japan (Todo and Shimizutani, 2008) and often involving collaboration with foreign universities (Granstrand, 1999; Florida, 1997).

Before proceeding, we note an important caveat of our analysis. While the use of cross-sectional data at the firm and host country level allows for a detailed analysis of the association between different types of R&D activities and firm and host country characteristics, it also has limitations. Because our study measures the state of foreign R&D activities captured at single point in time, the analysis can neither assess the process by which R&D location patterns have emerged and whether such patterns are changing over time, nor establish causal effects. We return to these issues in the final section of this study.

BACKGROUND AND THEORY

There is a broad literature suggesting that locating close to academic research and conducting formal collaborative research with academia can increase the innovative performance of firms (e.g. Jaffe, 1989; Acs et al., 1991 and 1994; Gambardella, 1992; Mansfield, 1995; Cockburn and Henderson, 1998; Cohen et al., 2002; Zucker et al., 2002; Belderbos et al., 2004; Fleming and Sorenson, 2004; Link et al., 2007; Leten al., 2007; Cassiman et al., 2008; Jaffe, 1989; Zucker et al., 2002). By locating R&D close to universities, firms can benefit in at least two important ways (Hall et al., 2003). First, universities educate and supply firms with a skilled

labour force of scientists and engineers. Second, academic research can directly provide useful knowledge for firms' innovation efforts. Academic research generates basic scientific knowledge on which firms can draw in their own basic and applied R&D activities (Klevorick et al., 1995; Mansfield, 1995 and 1998). This can enable firms to develop a deeper understanding of the technological landscape (Rosenberg, 1990; Fleming and Sorenson, 2004), to anticipate results of development projects and experiments to avoid costly and time consuming trials (Fleming and Sorenson, 2004; Fabrizio, 2009), and to better evaluate the outcomes of their applied research (Rosenberg, 1990).

In order to reap the benefits of academic research at universities and translate academic research into industrial application, active research collaboration between firms and universities is often instrumental (Markiewicz, 2004; Cockburn and Henderson, 1998; Zucker and Darby, 2001; Belderbos, Gilsing, Suzuki, 2016). In general, the intensity of such linkages between universities and firms in a country is dependent on national institutions and innovation systems. Government initiatives such as the establishment of organizations and funds encouraging collaborations, and legislating facilitating it, can promote intensive linkages between universities and firms (Nelson, 1993). For example, the Bayh-Dole Act in the United States, which allowed US firms to patent and license federally funded research, arguably has had an important impact on patenting activity of US universities and industry funding for academic research (Mowery and Sampat, 2006). In particular since firm-industry collaboration is amenable to policy, it is important to examine its role in attracting foreign R&D investment.

Collaborative research with industry often has features that are distinct from scientific research by universities not involving such collaboration. Collaborative research tends to be

of an applied nature (Hicks and Hamilton, 1999; Godin and Gingras, 2000). Firms providing funding generally have influence on research directions and have an interest in aiming at generating insights useful for process improvements and product development. The best achievements of applied research often stem from face-to-face knowledge exchange between academic and industrial researchers involved in the collaborative projects (Balconi and Laboranti, 2006), and there is a strong association between faculty members' specialization in applied research and industry collaboration (Florida and Cohen, 1999).

On the other hand, prior studies have also suggested collaborating on basic research with universities can result in stronger innovative performance by firms in the life sciences sector (Gambardella, 1992; Cockburn and Henderson 1998; Fabrizio 2009). Perhaps because of firms' focus on commercialization and application of scientific results, involvement of industrial partners in scientific research on average has a relatively high impact: publications co-authored by firms and universities tend to have a significantly higher citation rate (Hick and Hamilton, 1999). Overall, these findings suggest that it is of interest to examine to what extent locations with greater university-industry collaboration are attractive to foreign multinationals' R&D investments, and in particular, for what type of R&D activity local collaboration is most important.

Despite the evidence of the important influence of university research and firm-university collaboration on industrial innovation, prior studies have not given due attention to the role of university research as an attractor of R&D in the context of international R&D location decisions. Survey research among managers of multinational firms has suggested that firms decide on foreign R&D locations not only on the basis of the expertise of university faculty but also based on the possibility to collaborate with university researchers (Thursby and

Thursby, 2006). Cantwell and Piscitello (2005) observed a positive association between public R&D employment and aggregate R&D activities of foreign controlled firms across European regions. Hegde and Hicks (2008) noted a positive correlation between industry aggregates of US MNCs' foreign R&D expenditures and science and engineering publications in host countries. Alcacer and Chung (2007) found a positive influence of the presence of patenting by local universities on foreign firms' propensity to invest in US regions, but their analysis was concerned with manufacturing investments rather than R&D activities. Belderbos et al. (2014) observed a positive influence of academic research strength on foreign firms' R&D investment location decisions for a sample of R&D investments in European regions. None of these studies examined the potential role of university collaboration opportunities.

Another aspect that has been largely overlooked in prior studies is that the locational drivers of R&D investments are likely to differ between basic research, applied research, and development activities targeting various markets. A small number of prior studies has been able to make a distinction between research on the one hand, and development on the other. Shimizutani and Todo (2008) showed that Japanese research-oriented activities are attracted to countries with advanced technology, while development-oriented activities are more likely to be located in host countries with large markets. Belderbos et al. (2009) and Kuemmerle (1999) observed similar patterns, with host country demand (growth) influencing foreign development expenditures and local technological opportunities and local R&D attracting investments in foreign research activities. Sachwald (2008) classified the motivation and tasks of foreign R&D units and host country facilitators: a strong technological and scientific environment matters for research laboratories, cost performance is important for global development centres, and local markets opportunities are key for local development centres.

In this paper, we examine the extent to which the strength of university research and the intensity of university-industry collaborations in host countries influence the propensity of foreign multinational firms to locate various types of R&D activities in their host countries. Specifically, we examine foreign R&D activities of 498 Japanese multinational firms in 24 host countries in 1996, distinguishing research versus development, and subsequently basic research, applied research, development for global markets, and development for local markets. We estimate two-stage models, analysing the propensity to conduct R&D in a host country in the first stage, and focusing on the choice of types of R&D activities in the second stage. We calculate industry-specific measures of host countries' academic research strength and university- industry research collaboration by drawing on publication data covering authors, locations and academic fields drawn from Thomson Reuters' Web of Science database. Our analysis controls for the potential role of market and cost factors, the strength or intellectual property rights protection, host country experience, and the extent to which the firm undertakes other value chain activities in the host country.

DATA, METHODS, AND VARIABLES

Data

Our analysis draws on unpublished data from the *Survey of Overseas Business Activities* conducted by the Ministry of Economy, Trade and Industry of Japan for fiscal year 1996 (the year ending March 31, 1997). The database provides information on Japanese parent firms and the activities conducted by each of their foreign affiliates. The affiliate data allows us to distinguish whether R&D activities are conducted in the affiliates, and if so, what types of R&D activities. Here we draw on questions concerning the role and function of the foreign

affiliates. Responding firms can tick multiple answers, among which basic research, applied research, development for global markets, and development for local markets.¹

We selected parent firms active in manufacturing industries and operating at least one manufacturing affiliate abroad. The official survey contains information on 1260 firms. While foreign affiliates are well identified, the response rate for the specific questions on R&D activities is relatively low. The analysis therefore had to be restricted to multinational firms' activities in host countries for which affiliate data allowed identification of the presence of R&D activities and their type. For 498 firms the survey contained enough information to construct the explanatory variables and to determine whether and what type of R&D activities were conducted in at least on host country in which the firm operated. We note that the sampling steps tend to lead to a relative overrepresentation of larger and R&D intensive multinational firms. On average, the sales volume of sample firms was 254 billion yen, versus 181 billion yen for all manufacturing firms in the survey. In terms of R&D, the sample firms on average reported an intensity of 3,62 percent, while this was 1,70 percent for manufacturing firms excluded from the sample. Hence, caution should be exercised in the interpretation of our findings, and results may be less representative for smaller and less R&D intensive multinational firms.²

¹ While a subset of respondents also reports the amount of R&D expenditures, the data does not allow allocating expenditures to the specific types of R&D.

² The R&D intensity of firms not selected refers to 570 manufacturing firms for which R&D information was available. Since R&D intensive firms are overrepresented in our sample, there is no evidence that results are affected by another potential concern: that the most R&D intensive firms refrain from reporting overseas R&D activities to avoid disclosure of strategic information.

We only included those host countries in which the firm operates affiliates, which makes it more likely that host countries are actually ‘at risk’ of attracting R&D activities of the firms.³ If firms have more than one affiliate in a host country, we aggregated over affiliates to arrive at a firm-host country observation. In total this left us with a sample of 1452 observations at the level of firm-host countries, including 24 different countries. Among these, in 222 cases R&D activities were reported in local affiliates.

The distribution of foreign affiliates and R&D activities of the sample firms over host countries is shown in Table 1. Among the 1452 host country operations of the 498 firms (on average, each firm is active in three countries), there are 222 instances of R&D operations. Almost all R&D units (except 3) engage in development activities (219) and in particular local development (216), while research activities are less frequent (150 cases). Among the four types of R&D activities, development for local markets is most common while basic research is least common. Among the 24 host countries, the United States (88) hosts the largest number of R&D units, followed by Taiwan (33), the United Kingdom (19) and South Korea (17).

Insert Table 1

Different types of R&D activities are often combined in firms’ R&D units in host countries, as is shown by Table 2. Among the 222 cases of R&D activities, 102 combine all four types of

³ This also allows focusing on the most relevant countries for employing R&D activities and the potential relationship between the nature of host country operations of the multinational firms and their specific R&D activities. We do note that this approach can not exclude concerns of selection bias in the first stage analysis, although the broad set of explanatory variables and the heterogeneity of countries included in the analysis may mitigate such concerns.

R&D activities, and 27 other R&D units combine three activities. The only type of R&D activity that is often conducted exclusively is local development (46).

Insert Table 2

Empirical Model and Dependent Variables

While we are interested in the drivers of firms' decisions to conduct R&D activities in the host countries in which they are active, we are specifically interested in the type of R&D activities that the firm engages in. This is best modelled as a two-stage process, where in the first stage the choice between conducting R&D activities in a host country or not is analysed, and in a second stage the choice between different types of activities. Since the first stage is the selection equation of the second stage, we estimate Heckman probit models with selection (e.g. De Luca and Perotti, 2011).

The dependent variable in the selection equation is the binary variable *R&D* taking the value one if a firm conducts any of the four types of R&D activities in a host country. Given that R&D activities are often combined and that there is a general lack of exclusive types (with the exception of local development), we estimate a number of different second stage models. First, we model the second stage as the choice between configurations including research, and configurations only including development activities; the variable *Research* takes the value 1 if a firm conducts basic or applied research, and zero otherwise. Second, to analyse the differences among the four R&D activities, we model the second stage as the choice between configurations including or excluding the specific type of R&D: *Basic Research*, *Applied Research*, and *Development for Global markets*. Because local development almost always present, this approach cannot be adopted for this R&D type. Instead, we model the second

stage as the choice between engagement in *only local development* (which is relatively often observed) or not.

We cluster error terms at the parent firm level in each model in order to control for correlations due to unobserved firm characteristics. Instruments in the first stage are a variable measuring firms' relative sales in the host country, parent firm size and a set of industry dummies.

Independent Variables

University strength and industry-university collaboration

The strength of university research of a host country and the intensity of collaboration between universities and firms are the key explanatory variables of interest. To measure these host country traits, we calculate the number of university publications and co-authored publications by researchers from universities and firms in the country at the industry level.

We use information on scientific articles authored by university researchers published in peer reviewed journals recorded in the Web of Science (WoS) publication database. Publications are extracted from the Web of Science database of Thomson Scientific and only papers of the document type article, letter, note and review have been selected. Since the Web of Science only includes journals that are peer reviewed, adhere to standards of editorial policy, and have a threshold impact factor, the publication count of universities can be considered a measure of the output of high quality academic research at the level of host countries and industries.

Firm-university co-authored publications are taken as a measure of university-industry collaboration. Even though university-industry interactions may also occur through other channels, prior research has validated co-publication as a reliable indicator of collaborative research (Cockburn and Henderson, 1998; Fabrizio, 2009). Melin and Persson (1996) found

that only five percent of surveyed scientists indicated that firm collaboration does not always result in co-authored papers.

We base our indicators on Web of Science publications published in the year 1994, which have at least one author's address in one of the 24 host countries. We classified the publications into categories depending on the type of institute to which authors are affiliated (e.g. university, firm). First, we used search strings that contain keywords indicating universities to identify universities among author affiliations. The search string for universities contains keywords such as *university* and *college*, and name variants in other countries. The search string for firms contains keywords that refer to legal forms in the host countries, and the names of the 1000 largest R&D spending firms in the world drawing on the European Innovation Scoreboard (2008). We manually checked affiliations that were not classified by the search strings. We could classify at least 95 percent of publications in each host country. When a publication has authors affiliated to universities and authors affiliated to firms, the publication was classified as a co-authored publication indicative of university-industry collaboration.

The number of university publications and co-authored publications between universities and firms at the industry level is calculated in three steps. First, we calculate for each host country the number of each type of publications at the level of 240 scientific disciplines. Information on the scientific disciplines of publications is obtained by using information on the journal issues in which publications are published and the ISI science classification table that assigns journal issues to one or more science fields. Second, we assign each academic field to a technology class (IPC 4-digit patent classes) by using the science-technology concordance table developed by Van Looy et al. (2004). This concordance table is based on the frequencies

with which patents (in various technology classes) cite publications (in various science fields). Finally, the publication counts at the technology field level are converted to counts at the ISIC industry classification (22 manufacturing sectors) using the technology-industry concordance table due to Verspagen et al. (1994).

Using the publication data, we construct two explanatory variables of interest. The first variable, *university research strength* in a host country, is measured as the number of publications authored by university researchers in the host country categorized as relevant to the firm's industry, scaled by the production level of the industry in the host country. The scaling by industry size takes into account the possibility that the costs of access to academic knowledge increases if a firm has to share knowledge sources with many competing firms (Adams and Jaffe, 1996). It also serves to reduce the correlations with host country variables such as technology strength and market size.

Second, we construct the variable *university-industry collaboration*, which measures the share (in percentage) of co-authored publications by researchers from host country universities and firms in total university publications in the host country at the industry level. The shares of co-authored publications by country and industry are shown in the appendix. The US, European countries and South Korea show relatively large shares of co-publications (2 to 4,5 percent). The co-publication intensity varies across industries within a country, with the highest percentages recorded for countries and sectors in which large R&D intensive firms are active, such as electronics in South Korea, and aerospace in the US.

Other explanatory variables

We include a set of firm and host country characteristics that have been found to influence foreign R&D in previous studies. We include the host country's *technological strength* in the industry, measured by the number of patent applications originating in the host country in the technology field relevant to the firm's industry. To avoid possible geographical bias we count patents by selecting 'triadic patents': patents applied for at the European Patent Office, the United States Patent and Trademark Office, and the Japan Patent Office.

Countries with large markets should also attract more foreign R&D. *Market size* is defined as the sum of host country production and imports minus exports for the industry of the firm. Data are drawn from the OECD STAN database and UNIDO industrial yearbooks. Higher *wage costs* of R&D personnel in the country may reduce the attractiveness for inward foreign R&D. Yearly gross income levels of engineers from the 1994 UBS 'Price and Earnings' reports are taken as indicator of these wage costs. The analysis also takes into account the host country's level of *IPR protection*, by including the 1995 patent rights index from Park and Wagh (2002). This index is constructed based on five aspects of patent laws such as coverage, duration, and enforcement. The index ranges between 0 and 5, with high scores for IPR systems that are highly aligned with international standards. IPR protection is likely to encourage R&D investments (e.g. Branstetter et al., 2006).

The likelihood that a host country attracts foreign R&D may also be related to the geographic distance between the host and home country of the focal firm, as the cost of R&D coordination and doing business abroad rises with distance (e.g. Belderbos et al., 2008; Nobel and Birkinshaw, 1998). To capture this influence, *Distance from Japan* is included and measures the distance between the capital city of the host country and Tokyo.

We include various firm characteristics both at the level of parent firms and their foreign activities in the host countries. We include the variable *parent firm size*, measured as the value of parent firm sales. Larger firms may have more resources to invest in R&D. We also include a dummy variable *parent firm basic research* to consider the research orientation of parent firms. This variable takes the value 1 if a parent firm conducts basic research in Japan. We add four variables to take into consideration characteristics of a firm's activities in a host country. The variables capture collocation benefits of R&D. *Host country experience* is measured as the number of years since the establishment of the firm's first affiliate in the host country. Firms have been found to gradually increase R&D activities in host countries as a function of cumulative experience (e.g. Belderbos, 2003, Shimizutani and Todo, 2008). Second, we take into account the size of host country operations and the strategic importance of these operations for the firm. *Affiliate relative sales* is the ratio of affiliates' sales in the host country to parent firm sales. Since R&D activities are likely to collocate with manufacturing activities, a third variable, *share of manufacturing*, is the ratio of host country manufacturing output (sales of manufacturing affiliates) to total host country sales of the firm. Fourth, we include *affiliate export* which takes the value 1 if the affiliate(s) of the firm are engaged in export activities. Affiliates with broader geographic mandates than only the host country are generally more likely to be assigned R&D mandates (Belderbos, 2003). Finally, 21 industry dummies are added (in the first stage) to capture differential importance of R&D across industries.

All the continuous variables except for the ratio variables are log-transformed. Summary statistics and correlations are presented in Table 3 for the full sample (selection equation) and the sample of firms-host country observations with positive R&D (222 observations). Most of the correlations between independent variables are moderate and do not raise multicollinearity

concerns. IPR protection exhibits relatively high correlations with university-industry collaboration (0,68 and 0,75) and wage costs (0,85 and 0,88). We return to this issue in the supplementary analysis section. An interesting observation in correlation table 3b is that, whereas university research strength and university collaboration are positively correlated with research and development for global markets, they are negatively correlated with R&D focusing solely on development for local markets. In the multivariate second stage analyses we will examine if this pattern is confirmed.

Insert Table 3

EMPIRICAL RESULTS

We first present results of the first stage probit analysis, after which we turn to the second stage models. The results of probit analyses relating the probability that a firm conducts R&D activities in a host country to host country and firm characteristics are presented in Table 4.

Insert Table 4

In Table 4, model 1 shows estimates with the university variables excluded, while model 2 adds the university variables. Model 1 shows expected signs for the control variables, with positive coefficients for technological strength, market size, IPR protection, firms' host country experience, firms' relative sales in the host country, the importance of firms' manufacturing activities relative to sales in the host country (manufacturing share), engagement in export activities, and involvement of the parent in basic research at home. The coefficients on wage costs and distance from Japan have are significant and negative, while only parent firm size has no significant association with the probability to conduct R&D in

host countries. In model 2, with the university variables included, we observe that their inclusion renders the coefficients of technological strength insignificant. The fit of the model improves significantly.⁴ University research strength has a significantly positive coefficient while the coefficient on the intensity of university-industry collaboration is positive but not significant.

The estimated coefficients give no direct indication of the magnitude of the associations. Calculations show that a standard deviation increase in university research strength on average is associated with an increase in the probability of conducting R&D by 39 percent. By comparison, a standard deviation increase in the relative size of firms' host country operations is associated with a 23 percent increase in the probability to engage in local R&D, while a standard deviation increase in the wage level is associated with a 38 percent decrease in this probability.

Insert Table 5

Table 5 shows the results of second stage models of the choice between different R&D type configurations, conditional on the fact that the firm is conducting R&D in the host country. The estimated coefficient on the selection parameter (atanrho), which is a function of the correlation between the first and second stage regressions, is not significant. This suggests that the first and second stage models are not significantly correlated. While this implies that the second stage models could also be estimated separately,⁵ we present the results of second stage models with selection for expositional completeness.

⁴ This finding is not related to the operationalization of the variable. If we scale technological strength with the size of the industry, similar finding are obtained.

⁵ Separate probit analyses of the second stage models confirmed that results were nearly identical.

We observe that the second stage models generally have less predictive power than the first stage model, with the models explaining the propensity to engage in basic research and development for global markets displaying an insignificant Wald test. This will be to an important extent due to the frequently occurring combinations of different types of R&D in host countries, rendering the distinction between R&D types less sharp. Nevertheless, the second stage analyses do bring out some salient differences. The coefficient of the university research variable is positive and significant (at the 10 percent level) in the basic research equation. University-industry collaboration has a significant association with research and applied research activities, while it is negatively associated with focused local development activities. These findings are consistent with the notions that firms' basic research activities are closest in nature to scientific research, while university-industry collaboration generally tends to focus on applied research. In particular for university-industry collaboration the implied strength of the association with (applied) research is substantial, with a standard deviation increase in the intensity of collaboration associated with an increase in the propensity to conduct (applied) research by about 45 percent.

The other significant differences are also of interest. Host country experience is associated with a higher propensities to conduct (applied) research. Research activities are also significantly associated with a greater importance of manufacturing activities of the firm in the host country, while local development activities have a negative association with it. These findings may suggest that firms often gradually expand R&D configurations, starting with development and extending to research once the local R&D unit has built up more experience. The probability that R&D only focuses on local development activities is negatively associated with export, while the likelihood that R&D activities include development for

global markets is negatively associated with local market size – both associations are intuitive.

Supplementary Analysis

We estimated a number of alternative specifications to examine the robustness of the empirical results. First, we explored the potential role of firm heterogeneity in response to university strength due to differences in firms' absorptive capacity to recognize, absorb and utilize academic scientific knowledge (Cohen and Levinthal, 1990; Gambardella, 1992; Liebeskind et al., 1996; Cockburn and Henderson, 1998; Fabrizio, 2009). Although our sample consists of relatively large multinational firms and close to 81 percent of the sample firms (92 percent of the sample firms in the second stage models) are engaged in basic research activities at home, the sample firms may value university strength and collaboration opportunities differently depending on their research organization and orientation. We exploit the available information on basic research orientation of the parent firms, as engagement in basic research is likely to be associated with the presence of in-house scientists and greater absorptive capacity for scientific knowledge. We examine whether the absence of such a basic research orientation reduces the influence of university research and university-industry collaboration on R&D choices, both in the first stage and the second stage models.

Insert Table 6

Table 6 presents the results of the first stage model (in the first column) and the different second stage models. In the first stage model (R&D), the interaction between the dummy variable 'no basic research orientation' and university research strength has a negative coefficient that is significant at the 10 percent level, suggesting that university research

strength does not attract R&D by firms without a basic research orientation. The coefficient of the interaction term with university-industry collaboration is also negative but not significant.

The second stage models have to be interpreted cautiously, as these involve only 19 cases of parent firms without a basic R&D orientation.⁶ The general pattern does show that the associations between university strength and collaboration on the one hand, and types of local R&D configurations on the other, are rather different for these firms. The interaction term between firms' lack of basic research orientation and university research strength is significantly negative for configurations with (basic or applied) research and global development, but positive with R&D involving only local development. In contrast, the interaction term with university-industry collaboration is positive and significant for R&D configurations involving development for global markets or basic research, and negative for R&D involving local development only. The results may be taken to suggest that firms lacking a basic research orientation only value university research and invest in broader local R&D mandates if university research focuses on collaboration and has a more applied character.

Second, we explored the sensitivity of the results to potential multicollinearity concerns, in light of the high correlation observed between the IPR protection variable and university-industry collaboration. Leaving IPR protection out of the first stage empirical models reduce the standard error of the coefficients estimated for university-industry collaboration: the coefficient now became significant. In the second stage models, no differences were observed. Hence, the fact that university-industry collaboration tends to be a

⁶ This appears to generate some implausibly large coefficient estimates in the second stage regressions.

feature of countries with stronger IPR protection renders it difficult to disentangle the precise association between collaboration and firms' propensity to engage in local R&D.

DISCUSSION AND CONCLUSION

The empirical analysis of Japanese firms' R&D activities in host countries provides clear evidence that the strength of university research in host countries is associated with a greater likelihood that firms invest in local R&D. Conditional on the presence of R&D in the host country, university strength is associated with a greater propensity that R&D activities include basic R&D. These findings add to the scarce set of empirical results suggesting an important role of university research in attracting multinational firms' R&D investments (Cantwell and Piscitello, 2005; Belderbos et al., 2014) and survey evidence indicating that firms take the presence of strong universities into account when they decide on international R&D allocation (Thursby and Thursby, 2006).

At the same time, our findings suggest that even among a set of large and R&D intensive multinational firms, there is heterogeneity in the influence of university research strength. The positive association between (basic) R&D activities in host countries and university strength is only observed for parent firms that conduct basic research activities, presumably because only these firms have the associated R&D orientation and absorptive capacity to draw and build on scientific knowledge in their R&D activities abroad. This confirms the notion that scientific knowledge is not a free good, but that firms aiming to take advantage of it need to accumulate the required knowledge and skills to understand and utilize this knowledge (Fabrizio, 2009; Cassiman and Veugelers, 2006).

A salient finding of our study concerns the specific role of university-industry collaboration. This is one of the mechanisms through which academic knowledge and expertise is transferred to firms, and it has been suggested that university collaboration opportunities are a particular factor taken into consideration by multinational firms when deciding on R&D

locations (Thursby and Thursby, 2006). Our findings suggest that the intensity of local university-industry collaborations in relevant domains for the investing firms is indeed important. It is positively associated with investments in applied research activities and negatively associated with more limited R&D mandates focusing only on local development. In addition, collaboration appears particularly relevant to firms lacking a basic R&D orientation when it comes to extending local R&D to include research and development for global markets.

These observed patterns are likely to be related to the more applied nature of collaborative university research. Applied research is the most typical domain of collaborative research by university scientists and firms across industries, as applied scientific research can feed into development and commercial applications sought by collaborating firms. Since incentives for universities to collaborate with industry are amenable to various public policies, such as conditional research grants and regulations concerning university patenting, these nuanced findings on the attraction of collaboration to specific types of firms and R&D activities may have important policy implications. Future research should examine the robustness of these relationships in different contexts. An interesting avenue for further research in this regard is to differentiate (collaborative) publication efforts of university scientists by type of publication, distinguishing publications as a function of their basic or applied nature (e.g. Lim et al, 2004).

We note that our use of indicators of university strength and university-industry collaboration based on relevant output in terms of scientific publication, does not suggest that increasing such output as such would be a policy objective. Instead, the presence of strong academic research will indicate opportunities for firms to get involved in local scientific networks and

to hire capable graduates and doctoral researchers from these universities. A pertinent limitation of our study is that we cannot identify the exact mechanisms of industry-university linkages - apart from the important role of the intensity of university-industry collaboration. We suggest that further research should aim to disentangle the industry-science knowledge transfer mechanisms and the university characteristics that are most effective in attracting foreign R&D and that influence firms' local R&D type configurations.

Finally, our analysis noted a strong relationship between the propensity to conduct local R&D and the depth and mandates of firms' affiliates in the host country. R&D activities are closely associated with experience in the host country, the relative size of operations in the host country, the manufacturing depth of operations, and broader mandates of affiliates in the form of export orientation. These results are in line with recent work suggesting the importance of the advantages of collocation of firms' value chain activities, in particular the advantages of close proximity and interaction between manufacturing and R&D (Belderbos et al., 2014; Defever 2006; 2012; Alcacer and Delgado, 2013; Alcacer, 2006). Our findings suggest more specifically that extension of R&D mandates to cover (applied) research is associated with stronger manufacturing mandates and experience the host country.

Our study is subject to a number of other limitations. First, an obvious limitation is that our analysis is based on a cross-section of firms and their host country affiliates in one specific year, 1996. More recent official data on overseas R&D by Japanese multinational firms suggest on the one hand a considerable stability in Japanese overseas R&D in the last two decades. The ratio of overseas R&D expenditures to overall R&D (the total of domestic R&D expenditures in Japan and overseas R&D) was below 2.3 percent in 1996. It rose to about 3,5 percent in the years after, but fluctuated around 3-4 percent in the first decade of this century.

Only very recently, the ratio increased to around 5 percent.⁷ On the other hand, the country distribution of foreign R&D shows a further shift to Asia. In terms of R&D performing affiliates, the share of Asia increased from 34 percent (our sample) to 62 percent in 2013, at the cost of the share of European and US affiliates (from 22 to 13 and from 40 to 21 percent, respectively). The shift is less pronounced if the volume of R&D expenditures is taken into account: here the US remains most important with a 48 percent share in 2013, followed by Asia (31 percent) and Europe (18 percent). The growing importance of Asia is likely to reflect the increased concentration of Japanese manufacturing FDI in the Asian region, the rapid growth of Asian markets, and the increasing technological and (scientific) research strength of Asian countries. While this does not suggest that motivations for R&D have changed strongly over time, it would be important to study these relationships in a more recent period to examine whether the role of university research in R&D location decisions has become more pronounced. Unfortunately, the official surveys of METI in more recent years no longer ask systematically for information on types of R&D activities.

Second, given the nature of the data and the lack of information on the exact timing of R&D decisions, our analysis was unable to identify causal effects, and the results have to be interpreted as associations and partial correlations.⁸ Third, a challenge for future research is to combine a global perspective on foreign R&D with spatially disaggregated analysis at the regional level to take into account that knowledge flows are a positive function of geographic

⁷ Data reported by METI. Note that the reported ratios underestimate the actual foreign R&D intensity, as they do not correct for non-response in case of foreign R&D, while the response rate to the mandatory domestic R&D survey is close to 100 percent.

⁸ It is even conceivable that focal firms' R&D units in a host country contribute to the university-industry collaboration if they have been engaged in effective collaboration in the past. The risk of such reverse causality will be limited since individual Japanese firms are not likely to have a major impact on overall university-industry collaboration in host countries.

proximity (Jaffe, 1989; Anselin et al, 1997; Belenzon and Shankerman, 2013) – although there is also evidence that firms value quality of research over proximity (Laursen et al., 2011; Okamuro and Nishimura, 2013). Our study used countries as the demarcation of location decisions, which is a natural starting point from a perspective of global R&D. Combining this global perspective with more fine grained regional location characteristics is a promising avenue for future research but faces important hurdles in terms calculating reliable indicators of fine-grained publication data and other comparable indicators on regions in a global context.

Acknowledgements

This research was conducted as a part of the RIETI research project “East Asian Firm-Level Productivity”. We thank Bart Thijs and Wolfgang Glanzel for assistance in the analysis of ISI publication data at the Centre for R&D Monitoring (ECOOM) of the University of Leuven. The authors are grateful to Leo Sleuwaegen, Kyoji Fukao, Juan Alcacer and an anonymous referee for comments on earlier drafts.

REFERENCES

- Acs Z., Audretsch D. & Feldman M. (1991). Real effects of academic research: Comment. *American Economic Review*, 81, 363-367.
- Acs Z., Audretsch D. & Feldman M. (1994). R&D spillovers and recipient firm size. *The Review of Economics and Statistics*, 76, 336-340.
- Adams J. & Jaffe A., (1996). Bounding the Effects of R&D: An Investigation Using Matched Establishment-Firm Data, *RAND Journal of Economics*, The RAND Corporation, vol. 27(4), pages 700-721, Winter
- Alcacer J. & Chung W. (2007). Location strategies and knowledge spillovers. *Management Science*, 53(5), 760-776.

- Alcacer J. (2006). Location choices across the value chain: How activity and capability influence collocation. *Management Science*, 52(10), 1457-1471.
- Alcacer, J. & Delgado, M. (2013). Spatial organization of firms and location choices through the value chain. *Harvard Business School*: 13-025.
- Anselin L., Varga A. & Acs Z. (1997). Local geographic spillovers between university research and high technology innovations. *Journal of Urban Economics*, 42, 422-448
- Balconi, M. & Laboranti, A. (2006). University–industry interactions in applied research: The case of microelectronics. *Research Policy*, 35: 1616–1630.
- Belderbos R., Carree M. & Lokshin B. (2004). R&D cooperation and firm performance. *Research Policy*, 33(10), 1477-1492.
- Belderbos R., Lykogianni E. & Veugelers R. (2008). Strategic R&D location in European Manufacturing Industries. *Journal of World Economics*, 14 (2).
- Belderbos, R, Fukao. K. & Iwasa, T, (2009). Domestic and Foreign R&D Investment, *Journal of the Economics of Innovation and New Technologies*, 18 (4), 369–380.
- Belderbos, R. (2003). Entry mode, organizational learning, and R&D in foreign affiliates: Evidence from Japanese firms. *Strategic Management Journal*, 24(3): 235-259.
- Belderbos, R., Van Roy, V., Leten, B., & Thijs, B. (2014). Academic research strengths and multinational firms' foreign R&D location decisions: evidence from R&D investments in European regions. *Environment and Planning A*, 46(4): 920-942.
- Belderbos, R., Gilsing, V. and Suzuki, S. (2016). Direct and mediated ties to universities: 'scientific' absorptive capacity and innovation performance of pharmaceutical firms, *Strategic Organization*, 14(1), 32-52, 2016
- Belenzon, S. & Schankerman, M. (2013). Spreading the Word: Geography, Policy, and Knowledge Spillovers. *The Review of Economics and Statistics*, 95(3), 884-903.
- Branstetter L., Fisman R. & Foley C.F. (2006). Do Stronger Intellectual Property Rights Increase International Knowledge Transfer? Empirical Evidence from U.S. Firm-Level Panel Data. *Quarterly Journal of Economics*, 121(1), 321-349.
- Cantwell J. & Piscitello L., (2005). Recent location of foreign-owned research and development activities by large multinational corporations in the European regions: The role of spillovers and externalities. *Regional Studies*, 39, 1-16.
- Cassiman B. & Veugelers R. (2006). In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. *Management Science*, 52(1), 68-82.
- Cassiman B., Veugelers R. & Zuniga P. (2008). In search of performance effects of (in) direct industry science links. *Industrial and Corporate Change* vol. 17, no. 4, pp. 611 - 646.
- Chung, W. & Yeaple, S. (2008). International knowledge sourcing: evidence from US firms expanding abroad. *Strategic Management Journal*, 29 (11): 1207-1224.

- Cockburn I. & Henderson R. (1998). Absorptive Capacity, Co-authoring behaviour, and the Organization of Research in Drug Discovery. *Journal of Industrial Economics*, 46(2), 157-182.
- Cohen W., Nelson R. & Walsh J. (2002). Links and impacts: The influence of public research on industrial R&D. *Management Science*, 48(1), 1-23.
- Cohen, W. & Levinthal D. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, Vol. 35, 128-152
- De Luca, G., and V. Perotti. 2011. Estimation of ordered response models with sample selection. *Stata Journal* 11: 213–239.
- Defever, F. (2006). Functional fragmentation and the location of multinational firms in the enlarged Europe. *Regional Science and Urban Economics*, 36(5): 658-677.
- Defever, F. (2012). The spatial organization of multinational firms. *Canadian Journal of Economics/Revue canadienne d'économique*, 45(2): 672-697.
- Fabrizio K. (2009). Absorptive capacity and the search for innovation. *Research Policy*, (38(2), 255-267.
- Fleming L. & Sorenson O. (2004). Science as a map in technological search. *Strategic Management Journal*, 25, 909-928.
- Florida R. (1997). The globalization of R&D: Results of a survey of foreign -affiliated R&D laboratories in the USA. *Research Policy*, 26, 85-103.
- Florida, R. & Cohen, W.M. (1999). Engine or infrastructure? The university role in economic development. In: Branscomb, L.M., Kodama, F., Florida, R. (Eds.), *Industrializing Knowledge: University–Industry Linkages in Japan and the United States*. MIT Press, London.
- Gambardella A. (1992). Competitive advantages from in-house scientific research: The US pharmaceutical industry in the 1980s. *Research Policy*, 21, 391-407.
- Godin, B. & Gingras, Y. (2000). The impact of collaborative research on academic science. *Science and Public Policy*, 27 (1): 65–73.
- Granstrand, Ove (1999). Internationalization of corporate R&D: a study of Japanese and Swedish corporations, *Research Policy*, (28) 2-3, 275-302.
- Hall B.H., Link A. & Scott J. (2003) Universities as Research Partners, *The Review of Economics and Statistics*, MIT Press, vol. 85(2), pages 485-491, 01.
- Hegde D. & Hicks D. (2008). The maturation of global corporate R&D: Evidence from the activity of U.S. foreign subsidiaries. *Research Policy*, 390-406.
- Hicks, D. & Hamilton, K. (1999). Does university–industry collaboration adversely affect university research? *Issues in Science and Technology*, Summer 1999.
- Iwasa T. & Odagiri H. (2004). Overseas R&D, knowledge sourcing, and patenting: An empirical study of Japanese R&D investment in the US. *Research Policy*, 33 (5), 807-829.
- Jaffe, A., (1989). Real effects of academic research. *American Economic Review*, 79, 957-970.

- Kenney, M. and R. Florida (1994). The organization and geography of Japanese R&D: results from a survey of Japanese electronics and biotechnology firms, *Research Policy*, 23, 305-323
- Klevorick, A.K., Levin, R.C., Nelson, R.R., & Winter, S.G. (1995). On the sources and significance of interindustry differences in technological opportunities. *Research Policy* 24, 185–205.
- Kuemmerle W. (1997). Building Effective R&D Capabilities Abroad. *Harvard Business Review*, March / April, 61-70.
- Kuemmerle, W. (1999). The drivers of foreign direct investment into research and development: An empirical investigation. *Journal of International Business Studies*, 30(1): 1-24.
- Laursen, K., Reichstein, T., & Salter, A. (2011). Exploring the effect of geographical proximity and university quality on university–industry collaboration in the United Kingdom. *Regional Studies*, 45(4), 507-523.
- Leten B., Belderbos B. & Van Looy B. (2007). Technological diversification, coherence and performance of firms. *Journal of Product Innovation Management*, 24(6):567-579.
- Liebeskind J.P., Oliver A.L., Zucker L. & Brewer M. (1996). Social networks, learning, and flexibility: sourcing scientific knowledge in new biotechnology firms. *Organization Science*, 7(4): 428-442.
- Lim, K. (2004). The relationship between research and innovation in the semiconductor and pharmaceutical industries (1981-1997). *Research Policy*, 33, 287-321.
- Link, A.N., Siegel, D.S. & Bozeman, B. (2007). An empirical analysis of the propensity of academics to engage in informal university technology transfer , *Industrial and Corporate Change*, Oxford University Press, vol. 16(4), pages 641-655, August.
- Mansfield E. (1995). Academic research underlying industrial innovations: Sources, characteristics and financing. *The Review of Economics and Statistics*, 77, 55- 65.
- Mansfield E. (1998). Academic research and industrial innovation: An update of empirical findings. *Research Policy*, 26, 773-776.
- Markiewicz, K. (2004). Absorptive Capacity and Innovation: Evidence from Pharmaceutical and Biotechnology firms, working paper, UC-Berkeley.
- Melin, G., & Persson, O. (1996). Studying research collaboration using co-authorships. *Scientometrics*, 36(3), 363-377.
- METI (various years). *Survey of Overseas Business Activities* Ministry of Economy, International Trade and Industry, Tokyo.
- Moncada-Paternò-Castello, P., Vivarelli, M., & Voigt, P. (2011). Drivers and impacts in the globalization of corporate R&D: an introduction based on the European experience. *Industrial and Corporate Change*, 20(2): 585-603.
- Mowery D. & Sampat B. (2006) Universities in National Innovation Systems. In: Fagerberg, J., Mowery, D., Nelson, R. (Eds.), *The Oxford Handbook of Innovation*. Oxford University Press, Oxford.

- Nelson, R. (1993). *National Innovation Systems: A Comparative Analysis*. Oxford University Press, Oxford.
- Nobel R. & Birkinshaw J., (1998). Innovation in multinational corporations: control and communication patterns in international R&D operations, *Strategic Management Journal*, 19-5, 479-496.
- OECD 2011. *Attractiveness for Innovation: Location Factors for International Investment*, Directorate of Science Technology and Industry, Paris:OECD.
- Okamuro, H. & Nishimura, J., (2013). Impact of University Intellectual Property Policy on the Performance of University-industry Research Collaboration. *Journal of Technology Transfer*, 38(3), 273-301.
- Park W. & Wagh S. (2002). Index of patent rights. *Economic freedom of the world: 2002 annual report*, chapter 2, 33-43.
- Penner-Hahn, J. and Shaver, J. M. (2005). 'Does international research and development increase patent output? An analysis of Japanese pharmaceutical firms'. *Strategic Management Journal*, Vol. 26(2), pp. 121-140.
- Rosenberg N. (1990). Why do firms do basic research (with their own money)? *Research Policy*, 19(2), 165-174.
- Sachwald, F. (2008). Location choices within global innovation networks: the case of Europe. *Journal of Technology Transfer*, 33: 364-378.
- Shimizutani S. & Todo Y. (2008). What determines overseas R&D activities? The case of Japanese multinational firms. *Research Policy*, 37, 530–544.
- Song, J., Asakawa, K., & Chu, Y. 2011. What determines knowledge sourcing from host locations of overseas R&D operations?: A study of global R&D activities of Japanese multinationals. *Research Policy*, 40(3): 380-390.
- Statistics*, MIT Press, vol. 85(2), pages 485-491, 01.
- Thursby J. & Thursby M. (2006). Here or There? A Survey of Factors in Multinational R&D Location. *Report to the Government-University-Industry Research Roundtable*, National Academy of Sciences.
- Todo, Y., & Shimizutani, S. 2008. Overseas R&D activities and home productivity growth: Evidence from Japanese firm-level data. *Journal of Industrial Economics*, 56(4): 752-777.
- UNCTAD (2005). *World Investment Report 2005*, New York: United Nations.
- Van Looy, B., Tijssen, R.J.W. Callaert J, Van Leeuwen T. & Debackere K. (2004). European science in industrial relevant research areas: Development of an indicator-based bibliometric methodology for performance analyses of countries and research organizations, Report for the European Commission (DG Research) produced by CWTS (Leiden) and INCENTIM (Leuven).

- Verspagen B., van Moergastel, T. and Slabbers M. (1994). MERIT concordance table: IPC - ISIC (rev. 2). *MERIT Research Memorandum 2/94-004*
- Von Zedtwitz, M. and Gassmann, O. (2002). Market versus technology drive in R&D internationalization: four different patterns of managing research and development. *Research Policy*, **31**(4): 569-588.
- Westney, D. Eleanor (1994). The Evolution of Japan's Industrial Research and Development, in: Masahiko Aoki and Ronald Dore, eds. *The Japanese firm: The sources of competitive strength*, Oxford University Press, Oxford and New York, 154-177.
- Zucker L. & Darby M. (2001). Capturing Technological Opportunity via Japan's Star Scientists: Evidence from Japanese Firms' Biotech Patents and Products. *The Journal of Technology Transfer*, vol. 26(1-2), 37-58.
- Zucker L., Darby M., Armstrong J. (2002). Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology. *Management Science*, 48(1), 138-153.

Table 1. Distribution of Foreign R&D Activities by Japanese Multinational Firms by Host Country and Type of R&D

Country	Obs.	R&D	Research	Development	Basic Research	Applied Research	Development for Global Markets	Development for Local Markets
Australia	62	2	1	2	1	1	2	2
Belgium	3	2	2	2	2	2	1	2
Brazil	36	5	5	5	2	5	2	5
Canada	61	1	1	1	1	1	1	1
China	94	14	8	14	6	8	6	14
Germany	141	11	7	10	5	6	5	10
Spain	27	5	2	5	2	2	3	5
France	56	9	6	9	4	6	7	9
United Kingdom	118	19	11	19	8	11	15	19
Hong Kong	102	1	0	1	0	0	1	1
Hungary	3	0	0	0	0	0	0	0
Ireland	5	0	0	0	0	0	0	0
India	4	0	0	0	0	0	0	0
Italy	34	1	1	1	0	1	1	1
Korea	61	17	12	17	12	11	12	17
Mexico	29	1	1	1	1	1	1	1
Malaysia	12	2	1	2	1	1	2	2
Netherlands	57	3	3	3	0	3	2	2
Philippines	9	1	1	1	1	1	1	1
Sweden	18	0	0	0	0	0	0	0
Singapore	94	7	3	7	1	3	5	7
Thailand	3	0	0	0	0	0	0	0
Taiwan	134	33	21	32	17	21	17	32
United States	289	88	64	87	51	63	64	85
Total	1,452	222	150	219	115	147	148	216

Table 2: R&D Activities Abroad: Configurations of R&D types

<i>R&D activity configurations</i>	
basic, applied, global, local	102
basic, applied	1
basic, applied, local	9
basic, global, local	2
basic	1
applied, global, local	16
applied, global	2
applied, local	16
applied	1
global, local	25
global	1
local	46
Total	222

Notes: basic= basic research, applied=applied research,
global=development for global markets, local=development
for local markets

Table 3: Means, Standard Deviations and Correlation Coefficients.

Table 3a. Full sample (N=1452)

	Mean	Std. Dev.	1	2	3	4	5	6	7	8	9	10	11	12	13
1 R&D (Dep. Var.)	0,15	0,36													
2 Univ. Research Strength	0,09	0,18	-0,05												
3 University-Industry collaboration	2,46	1,88	0,16	0,03											
4 Technological Strength	0,13	0,29	0,08	0,35	0,40										
5 Market Size	10,33	1,28	0,15	-0,02	0,58	0,52									
6 Wage costs	10,69	0,90	0,01	0,14	0,51	0,25	0,19								
7 IPR Protection	1,25	0,31	0,08	0,19	0,68	0,38	0,40	0,85							
8 Distance from Japan	4,13	0,72	-0,01	0,25	0,47	0,32	0,33	0,54	0,64						
9 Host Country Experience	2,41	0,78	0,12	0,12	0,14	0,14	0,04	0,38	0,31	0,21					
10 Parent Firm Size	11,58	1,69	0,01	-0,04	-0,02	-0,16	-0,13	0,07	0,05	0,14	0,14				
11 Parent Basic Research	0,81	0,39	0,12	-0,05	0,06	0,00	-0,01	0,03	0,02	0,04	0,09	0,10			
12 Affiliate Relative Sales	0,06	0,13	0,15	0,01	0,09	0,13	0,19	0,11	0,14	0,02	0,13	-0,18	-0,07		
13 Manufacturing share	0,45	0,48	0,29	-0,18	-0,11	-0,10	0,05	-0,33	-0,27	-0,30	-0,04	-0,15	0,05	0,14	
14 Affiliate Export	0,81	0,39	0,14	-0,08	-0,03	0,01	-0,01	-0,03	-0,06	-0,07	0,03	0,06	-0,01	0,06	0,14

Table 3b. Subsample of observations with R&D activities (N=222)

	Mean	Std. Dev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Research (Dep. Var.)	0,68	0,47															
2 Basic Research (Dep. Var.)	0,52	0,50															
3 Applied Research (Dep. Var.)	0,66	0,47															
4 Global Development (Dep. Var.)	0,67	0,47															
5 Local Development (Dep. Var.)	0,21	0,41															
6 Univ. Research Strength	0,07	0,12	0,04	0,09	0,06	0,11	-0,09										
7 University-Industry collaboration	3,18	2,09	0,17	0,12	0,15	0,14	-0,12	0,13									
8 Technological Strength	0,19	0,34	0,03	0,09	0,03	0,02	-0,04	0,72	0,37								
9 Market Size	10,79	1,30	0,03	0,08	0,01	-0,04	0,03	0,19	0,63	0,52							
10 Wage costs	10,72	0,88	0,06	0,04	0,04	0,16	-0,15	0,21	0,59	0,28	0,30						
11 IPR Protection	1,31	0,33	0,08	0,06	0,07	0,17	-0,13	0,25	0,75	0,41	0,55	0,88					
12 Distance from Japan	4,11	0,82	0,07	-0,03	0,08	0,12	-0,14	0,30	0,53	0,38	0,50	0,55	0,62				
13 Host Country Experience	2,64	0,68	0,15	0,09	0,16	0,09	-0,13	0,12	0,13	0,19	0,05	0,37	0,33	0,10			
14 Parent Basic Research	0,92	0,27	0,04	0,08	0,07	0,04	-0,01	0,08	0,12	0,07	0,09	0,13	0,12	0,08	0,03		
15 Manufacturing share	0,78	0,36	0,20	0,14	0,20	-0,06	-0,06	-0,12	-0,14	-0,10	-0,10	-0,23	-0,21	-0,21	-0,14	-0,07	
16 Affiliate Export	0,94	0,24	0,14	0,08	0,13	0,13	-0,19	0,09	0,01	0,02	-0,03	0,11	0,08	0,10	0,15	-0,08	0,00

Table 4. Determinants of the propensity to conduct R&D in Host Countries

	R&D	
	Model 1	Model 2
Univ. Research Strength		1.1226*** (0.3804)
University-Industry collaboration		0.0625 (0.0488)
Technological Strength	0.4392** (0.2216)	0.2374 (0.2242)
Market Size	0.1466** (0.0572)	0.1381** (0.0595)
Wage costs	-0.2476** (0.1075)	-0.2292** (0.1109)
IPR Protection	0.9091*** (0.3228)	0.6304* (0.3721)
Distance from Japan	-0.1598** (0.0764)	-0.1957** (0.0811)
Host Country Experience	0.3321*** (0.0768)	0.3402*** (0.0795)
Parent Firm Size	0.0404 (0.0422)	0.0447 (0.0422)
Parent Basic Research	0.5346*** (0.1832)	0.5373*** (0.1844)
Affiliate Relative Sales	0.9268** (0.4025)	0.9653** (0.3962)
Manufacturing share	1.0794*** (0.1142)	1.0976*** (0.1139)
Affiliate Export	0.7149*** (0.1723)	0.7305*** (0.1725)
Industry Dummies	Included	Included
Constant	-3.3911*** (1.2382)	-3.3132*** (1.2819)
No. of Observations	1452	1452
No. of Firms	498	498
No. of Cases with R&D	222	222
Log Likelihood	-459.24	-456.24
Wald chi-square	263.30***	271.29***
Chi-square test model improvement		6.01**
McFadden's R-square	0.260	0.265

Notes: Results of probit models. ***, **, * indicate significance of coefficients at the 1, 5 and 10 percent levels. Clustered standard errors reported in parentheses.

Table 5. Determinants of the propensity to conduct specific types or R&D activities in Host Countries (conditional on the presence of R&D activities)

	Research	Basic Research	Applied Research	Development for Global Markets	Only Development for Local Markets
Univ. Research Strength	0.9525 (1.4769)	1.8932* (1.1087)	1.1995 (1.8737)	2.6664 (1.6679)	-0.6910 (1.9165)
University-Industry collaboration	0.2799*** (0.0741)	0.1035 (0.1558)	0.2769*** (0.0710)	0.0717 (0.0887)	-0.1938** (0.0789)
Technological Strength	-0.3981 (0.5907)	-0.3335 (0.4789)	-0.4596 (0.7006)	-0.7632 (0.5770)	0.1576 (0.6510)
Market Size	-0.1094 (0.1269)	0.0823 (0.1014)	-0.1507 (0.1323)	-0.2444** (0.1244)	0.2322 (0.1679)
Wage costs	-0.2738 (0.2996)	0.1049 (0.3267)	-0.3705 (0.2782)	-0.1603 (0.2887)	0.2346 (0.2863)
IPR Protection	-0.0630 (1.1311)	-0.6537 (1.0492)	0.1536 (1.1456)	0.7414 (1.0495)	-0.6125 (0.9762)
Distance from Japan	0.1142 (0.1538)	-0.2120 (0.2055)	0.1698 (0.1806)	0.0989 (0.1486)	-0.2011 (0.2031)
Host Country Experience	0.4738*** (0.1647)	0.1305 (0.3046)	0.5184*** (0.1554)	-0.0499 (0.1653)	-0.2904 (0.1823)
Parent Basic Research	0.4109 (0.4268)	0.1937 (0.6109)	0.5586 (0.3875)	-0.0988 (0.3060)	-0.3465 (0.4051)
Manufacturing share	1.1251*** (0.3504)	0.3639 (0.8571)	1.1952*** (0.3167)	-0.3761 (0.4021)	-0.7674* (0.4196)
Affiliate Export	0.7730* (0.4229)	0.2293 (0.7840)	0.7241* (0.4256)	0.1528 (0.4592)	-0.9293*** (0.3301)
Constant	-0.4262 (2.8749)	-1.2722 (3.1991)	0.1389 (2.9802)	4.0994 (2.6082)	-0.2322 (3.2357)
atanrho	0.4844 (0.9919)	-0.3621 (1.2403)	0.5971 (1.2668)	-0.5764 (0.5908)	-0.7558 (1.0555)
No. of Observations	222	222	222	222	222
No. of Firms	151	151	151	151	151
No. of cases R&D type is observed	150	115	147	148	46
Log Likelihood	-578.95	-600.11	-579.37	-586.05	-557.92
Wald chi-square	40.58***	5.45	57.85***	14.82	38.62***

Notes: Results of two-stage probit models with selection. ***, **, * indicate significance of coefficients at the 1, 5 and 10 percent levels. Clustered standard errors reported in parentheses. Atanrho is a function of the correlation between the first and second stage models.

Table 6. Empirical Results with Firm Heterogeneity

	R&D	Research	Basic Research	Applied Research	Development Glob. markets	Only Development Loc. Markets
Univ. Research Strength	1.3112*** (0.3809)	0.8923 (1.3706)	1.8844* (1.1310)	1.0806 (1.6812)	2.4905 (1.6801)	-0.6241 (1.6818)
Univ. Research Strength *	-2.0664* (1.1406)	-9.6932*** (3.5231)	-28.4734** (14.1284)	-7.5463** (3.1910)	-15.6532** (7.0031)	10.5151** (4.7378)
No Basic Research Parent						
University-Industry collaboration	0.0691 (0.0492)	0.2691*** (0.0709)	0.1040 (0.1556)	0.2633*** (0.0696)	0.0707 (0.0948)	-0.1874** (0.0757)
University-Industry collaboration *	-0.1016 (0.0927)	0.3466 (0.2746)	0.6033** (0.2576)	0.2593 (0.2740)	1.0529** (0.4229)	-0.3850 (0.3298)
No Basic Research Parent						
Technological Strength	0.2388 (0.2280)	-0.2412 (0.5650)	-0.2178 (0.5238)	-0.2994 (0.6541)	-0.6070 (0.5972)	-0.0182 (0.5796)
Market Size	0.1426** (0.0592)	-0.1053 (0.1260)	0.0876 (0.1073)	-0.1452 (0.1371)	-0.2694** (0.1285)	0.2224 (0.1746)
Wage costs	-0.2233** (0.1104)	-0.3463 (0.2730)	-0.0437 (0.3948)	-0.4317* (0.2381)	-0.2974 (0.3081)	0.2856 (0.2595)
IPR Protection	0.6306* (0.3735)	0.0299 (1.0973)	-0.4406 (1.2177)	0.2552 (1.0482)	0.8799 (1.0706)	-0.6072 (0.9152)
Distance from Japan	-0.1973** (0.0804)	0.1407 (0.1620)	-0.1849 (0.1721)	0.1876 (0.1990)	0.1537 (0.1629)	-0.2241 (0.2257)
Host Country Experience	0.3454*** (0.0795)	0.5499*** (0.1500)	0.2618 (0.3505)	0.5797*** (0.1426)	0.0661 (0.1925)	-0.3664** (0.1536)
Parent Basic Research	0.1389 (0.2631)	0.7048 (0.5244)	0.9296 (0.7352)	0.7974 (0.5110)	1.2082* (0.6359)	-0.5577 (0.5271)
Manufacturing share	1.0967*** (0.1148)	1.1748*** (0.2891)	0.4764 (0.8667)	1.2276*** (0.2455)	-0.2694 (0.4502)	-0.8189** (0.3879)
Affiliate Export	0.7370*** (0.1733)	0.7943** (0.3797)	0.3412 (0.8079)	0.7418** (0.3690)	0.2346 (0.4895)	-0.9222*** (0.3157)
Constant	-3.0759** (1.2764)	-0.6272 (2.7423)	-1.6589 (3.1920)	-0.0436 (2.8250)	3.5168 (2.7991)	-0.0280 (3.1482)
Parent Firm Size	0.0463 (0.0418)					
Affiliate Relative Sales	0.9138** (0.4167)					
atanrho		0.6544 (1.0746)	-0.1369 (1.3157)	0.7794 (1.3638)	-0.4093 (0.5870)	-0.8795 (1.1246)
No. of Observations	1452	222	222	222	222	222
No. of Firms	498	151	151	151	151	151
No. of cases R&D type is observed	222	150	115	147	148	46
Log Likelihood	-453.78	-573.94	-592.83	-574.81	-578.76	-552.82
Wald chi-square	275.61***	66.70***	14.10	86.07***	24.68**	56.43***

Notes: Results of two-stage probit models with selection. ***, **, * indicate significance of coefficients at the 1, 5 and 10 percent levels. Clustered standard errors reported in parentheses. The firms column (R&D) is the selection equation and also includes industry dummies. Firm heterogeneity is captured by parent firms' engagement in basic R&D in Japan.

Appendix: Shares of Universities-Firm Co-authored Publications by Country and Industry

Country	Total	Industry																					
		Elec Mach	Electronics	Chem	Pharm	Oil Ref	Ship Build	Motor Vehic	Aero space	Transport	Steel	Non Ferr Metals	Metal Prod	Instruments	Computer	Machinery	Food	Textile	Rubber Plast	Stone Glass	Paper Print	Wood	Other Prod
Australia	0.9%	0.5%	0.8%	1.1%	1.1%	3.4%	0.1%	0.2%	0.2%	0.6%	1.8%	1.6%	0.7%	0.9%	0.7%	1.0%	1.1%	1.0%	0.8%	1.4%	0.9%	1.0%	0.7%
Belgium	1.7%	0.9%	0.9%	1.8%	2.1%	2.4%	0.1%	2.8%	0.6%	4.9%	1.0%	0.8%	1.0%	1.7%	1.1%	1.6%	2.0%	1.8%	2.2%	1.5%	1.3%	1.8%	1.5%
Brazil	0.4%	0.4%	0.7%	0.5%	0.2%	2.7%	0.2%	0.8%	0.1%	1.2%	0.9%	0.8%	0.6%	0.3%	1.2%	0.6%	0.2%	0.8%	0.4%	3.1%	0.9%	0.7%	0.5%
Canada	1.9%	3.8%	3.7%	1.8%	1.3%	4.1%	2.3%	0.9%	2.2%	2.1%	4.8%	4.5%	3.4%	1.6%	1.7%	2.3%	1.5%	2.9%	1.3%	3.2%	4.5%	2.1%	1.8%
China	0.4%	0.8%	0.7%	0.2%	0.1%	0.2%	0.0%	0.3%	0.1%	0.1%	0.2%	0.4%	0.7%	0.5%	0.4%	0.4%	0.1%	0.2%	0.1%	0.6%	0.6%	0.1%	0.4%
France	4.1%	4.5%	4.3%	4.4%	4.4%	6.4%	0.7%	1.5%	2.5%	2.0%	3.6%	3.8%	4.3%	3.7%	2.5%	4.3%	5.2%	3.9%	3.6%	4.3%	4.8%	4.4%	4.5%
Germany	2.9%	3.9%	3.8%	2.9%	2.5%	5.3%	3.7%	1.8%	2.4%	3.1%	6.1%	5.0%	3.6%	2.8%	2.7%	3.2%	2.7%	3.6%	2.3%	4.3%	3.9%	2.4%	3.1%
Hong Kong	0.5%	0.5%	0.9%	0.4%	0.1%	1.3%	0.2%	0.1%	0.6%	0.5%	0.4%	0.2%	0.4%	0.4%	1.2%	0.7%	0.2%	0.1%	0.1%	2.9%	1.1%	0.1%	0.5%
Hungary	3.2%	3.0%	2.9%	3.2%	4.1%	2.7%	0.2%	1.5%	3.5%	1.6%	3.0%	2.3%	3.4%	3.2%	0.8%	3.1%	2.7%	2.9%	2.9%	2.0%	5.4%	3.7%	2.3%
India	0.8%	0.7%	0.7%	1.1%	0.6%	1.4%	0.2%	0.6%	0.5%	0.8%	2.9%	2.2%	1.0%	0.6%	0.7%	0.8%	0.3%	1.9%	0.7%	1.1%	0.9%	0.6%	1.1%
Ireland	0.6%	0.4%	0.9%	0.8%	0.6%	0.3%	0.1%	0.1%	0.1%	0.2%	0.9%	0.5%	0.4%	0.4%	1.3%	0.5%	0.5%	1.8%	0.5%	0.5%	0.4%	0.5%	0.9%
Italy	2.1%	2.1%	2.4%	2.2%	2.3%	3.3%	0.5%	1.9%	2.3%	2.2%	2.7%	2.4%	2.1%	2.0%	1.5%	2.1%	2.0%	2.0%	2.2%	2.1%	2.1%	2.2%	2.1%
Korea	2.8%	4.0%	3.9%	3.3%	1.9%	3.4%	0.4%	4.5%	2.7%	3.9%	4.9%	4.3%	4.0%	2.2%	2.4%	3.1%	1.6%	4.6%	2.4%	5.1%	2.8%	1.9%	3.5%
Malaysia	1.1%	0.2%	0.2%	0.9%	1.1%	0.3%	0.0%	0.2%	0.0%	0.1%	0.1%	0.1%	0.5%	1.0%	3.0%	1.1%	1.6%	0.1%	0.8%	0.1%	0.2%	0.7%	1.1%
Mexico	0.3%	0.2%	0.1%	0.4%	0.2%	0.6%	0.1%	1.6%	0.6%	2.1%	0.2%	0.2%	0.3%	0.2%	0.1%	0.5%	0.1%	0.9%	0.7%	0.4%	0.2%	0.2%	0.3%
Netherlands	2.5%	4.9%	4.2%	2.6%	2.0%	6.3%	0.2%	1.7%	3.1%	1.8%	9.6%	7.4%	4.1%	2.2%	2.0%	2.8%	1.9%	5.2%	1.8%	4.9%	3.4%	1.7%	2.9%
Philippines	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Singapore	1.4%	2.5%	2.5%	0.6%	1.0%	0.3%	0.0%	0.4%	0.3%	0.3%	0.8%	1.3%	1.6%	1.3%	1.7%	1.1%	1.0%	0.5%	0.5%	1.0%	1.1%	0.5%	1.2%
Spain	0.7%	0.6%	0.6%	0.8%	0.9%	0.5%	0.1%	0.5%	0.4%	0.8%	0.9%	0.7%	0.7%	0.7%	0.4%	0.7%	0.7%	1.3%	0.9%	1.6%	0.7%	0.8%	0.6%
Sweden	3.5%	3.2%	3.1%	3.7%	3.9%	4.1%	1.2%	3.1%	2.0%	4.2%	4.8%	3.5%	3.1%	3.6%	2.0%	3.4%	3.4%	3.2%	3.9%	4.1%	3.8%	3.5%	3.1%
Taiwan	1.0%	1.6%	1.7%	1.2%	0.5%	1.7%	0.1%	0.5%	0.3%	0.7%	1.6%	1.3%	1.3%	0.8%	1.1%	1.1%	0.4%	1.9%	0.5%	1.2%	1.6%	0.4%	1.1%
Thailand	0.2%	0.0%	0.0%	0.2%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.0%	0.1%	0.1%	0.3%	0.0%	0.0%	0.3%	0.1%	0.1%
United Kingdom	3.0%	3.4%	3.4%	3.5%	3.6%	4.4%	1.7%	0.9%	1.7%	2.2%	4.5%	4.8%	3.0%	2.7%	1.5%	3.1%	3.1%	4.9%	2.6%	3.7%	3.9%	2.9%	2.9%
United States	4.5%	6.8%	6.4%	4.3%	4.4%	6.2%	5.7%	1.9%	6.2%	4.2%	7.3%	7.4%	5.0%	4.1%	3.9%	4.4%	4.1%	6.0%	3.9%	7.5%	5.7%	3.9%	4.0%
Total	3.4%	4.5%	4.4%	3.4%	3.4%	4.8%	3.6%	1.5%	3.9%	3.2%	5.0%	4.8%	3.7%	3.2%	2.8%	3.4%	3.2%	4.4%	3.0%	4.8%	4.2%	3.1%	3.2%

Source: author calculations based on Thomson ISI.