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Does Excellence in Academic Research Attract Foreign R&D?*

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Abstract

We examine the role of host countries' academic research strengths in global R&D location decisions by multinational firms. While we expect that a firm's propensity to perform R&D in a host country increases with the strength of local academic research, firms are expected to be heterogeneously positioned to benefit from academic research strengths due to differences in the capacity to absorb and utilize scientific knowledge. We find support for these conjectures in an analysis of foreign R&D activities in 40 host countries and 30 technology fields by 176 leading European, US and Japanese firms during the periods 1995-1998 and 1999-2002. Controlling for a wide range of host country factors, the number of relevant ISI publications by scientists based in the host country has a substantial positive impact on the propensity to conduct foreign R&D. The effect of academic research is significantly larger for firms with a stronger science orientation in R&D - as indicated by citations to scientific literature in prior patents. For host countries with a strong relevant science base, this greater responsiveness of science oriented firms more than offsets a generally greater inclination to concentrate R&D at home. The findings appear robust across a variety of specifications.

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Introduction

An expanding literature on the importance of science for industrial research has suggested that proximity to, and involvement in, academic research, as well as formal collaborative research with academia increases the innovative performance of firms (e.g. Jaffe, 1989; Acs et al, 1991 & 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; Cassiman et al, 2008; Furman et al, 2006). Empirical studies have furthermore shown that academic research stimulates the growth of local industrial R&D and the set-up of new research intensive ventures in the region (e.g. Jaffe, 1989; Bania et al., 1992; Anselin et al., 1997; Zucker et al., 1998; Furman and MacGarvie, 2003; Abramovsky et al., 2007).

Surprisingly little attention has been given in this literature to the role of academic research in the R&D location decisions by multinational firms. It is important to examine this role, as foreign R&D activities represent an increasing share of the R&D activities of multinational firms and of total business R&D expenditures in host economies.[1] There are a number of partial exceptions that have suggested that the quality of academic research may be of importance to the presence of foreign R&D. These have focused on foreign R&D at the aggregate industry level (Hegde and Hicks, 2008; Cantwell and Piscitello, 2005) and/or on differences in foreign presence across regions in a single host country (Abramovsky et al., 2007; Alcacer and Chung, 2007).

In this paper we analyze global R&D location decisions by multinational firms at the micro level. R&D conducted in foreign affiliates has traditionally focused on the adaptation of home-developed technologies to foreign markets ('home base exploiting' or 'adaptive' R&D), but the evidence suggests that it has also become a vehicle to access foreign technological and scientific strengths and to create new technologies ('home base augmenting' or 'innovative' R&D) (Kuemmerle 1997; Von Zedtwitz and Gassmann, 2002; Shimizutani and Todo, 2008; Griffith et al, 2008; Belderbos, 2003; Belderbos et al., 2009; Penner Hahn and Shaver, 2005). Although empirical studies examining the determinants of foreign

[1] See OECD (2007) and UNCTAD (2005) for detailed evidence and overviews of R&D internationalization trends.

R&D have uncovered a number of host country factors affecting R&D investments (e.g. Odagiri & Yasuda, 1996; Kumar, 2001; Kuemmerle, 1999; Shimizutani and Todo, 2007; Belderbos et al, 2008; Branstetter et al. 2006), the role of the relevant academic research base of host countries has not been investigated.

We seek to understand in this paper to what extent the quantity and quality of academic research activities of (potential) host countries affect the propensity of multinational firms to undertake R&D in those countries. We examine R&D location decisions at the micro level, using data at the technology field level (30 fields) for 176 R&D intensive European, American and Japanese firms in the chemicals, pharmaceuticals, engineering, IT hardware and electronics industries in 40 host countries. The analysis takes into account technology specific strengths of countries and firms, and controls for a broad set of other host country and firm characteristics that have been found to attract or discourage international R&D in prior research. This allows us to determine the significance and magnitude of the impact of academic research with greater precision. Furthermore, we explore to what extent there is firm heterogeneity in the responsiveness of firms to academic research in their R&D location decisions (cf. Shaver and Flyer, 2000; Alcacer and Chung, 2007; Nachum et al., 2008). Firms may possess different capacities to recognize, absorb and utilize academic knowledge (Cohen and Levinthal, 1990; Gambardella, 1992; Fabrizio, 2009) depending on the scientific orientation of their research activities and organization (Furman, 2003; Liebeskind et al, 1996). Firms with a more outspoken science orientation in their R&D activities are likely to attach greater value to academic research in their international R&D strategies.

We examine R&D location decisions as derived from inventor locations on patent documents of the 176 firms and compare patterns across two periods (1995-1998 and 1999-2002) to assess a potentially strengthened role of university research in attracting R&D. Rather than measuring the strength of academic research by input measures (such as public R&D expenditures), we construct indicators of countries' scientific output using ISI publication data available at the level of countries and science fields. These country and technology field specific measures of scientific strength incorporate the quality of academic research as the ISI publication database includes reputable peer-reviewed journals. To measure the science orientation of firms' research activities, we count the number of non-patent references to scientific publications in firms' prior patent grants. We conduct a range of sensitivity analyses to examine the robustness of our empirical results.

The remainder of this paper is organized as follows. The next section provides a brief overview of prior research. Section 3 describes the characteristics of the dataset. The empirical model and variables are described in section 4. Section 5 presents the empirical results and we conclude in section 6.

DRIVERS OF FOREIGN R&D

Two streams of literature inform about the drivers of foreign R&D investments and the role of academic research for industrial R&D location decisions: the literature on R&D internationalization by multinational enterprises (MNEs) and the literature on industry science linkages.

International R&D

Studies on international R&D by multinational enterprises (MNEs) have identified two major motivations to set up foreign R&D activities (e.g. Hakanson and Nobel, 1993; Kuemmerle, 1997; Florida, 1997). Traditionally, MNEs have conducted R&D activities outside their home countries to support manufacturing activities of local subsidiaries or to adapt products and technologies developed in their home countries to local market conditions ('home base exploiting' or 'adaptive' R&D). A second major motivation for international R&D is to develop new technologies overseas by accessing foreign R&D resources and local technological and scientific strengths ('home base augmenting' or 'innovative' R&D). Empirical evidence suggests that home-base augmenting R&D is gaining importance in recent years (e.g. Florida, 1997; Kuemmerle, 1997; Von Zedtwitz and Gassmann, 2002; Ambos, 2005; Todo and Shimizutani, 2008; OECD, 2007). The rise in home base augmenting R&D has drawn renewed attention to the question to what extent home country operations can benefit from overseas R&D through 'reverse' technology transfer and the development and sharing of complementary technologies. Although some studies have indicated that knowledge flows from foreign affiliates back to headquarters have remained limited (Fors, 1997; Gupta and Govindarajan, 2000; Frost, 2001), recent evidence suggests that there are knowledge flows from host country organizations to foreign affiliates of MNE (Singh, 2007) and that foreign R&D can have a positive impact on the productivity of parent operations (Iwasa and Odagiri, 2004; Penner-Hahn and Shaver, 2005; Todo and Shimizutani, 2008; Griffith et al., 2008). Griffith et al. (2008) suggest that positive effects are conditional on embeddedness in foreign research networks (as proxied by citations by the foreign affiliates to host country patents). Positive impacts on home country operations have also suggested to be conditional on technological strengths of host locations (Iwasa and Odagiri, 2004), a sufficient 'absorptive capacity' at corporate headquarters to utilize foreign R&D results (Penner-Hahn and Shaver, 2005; Song and Shin). Singh (2008) furthermore suggests that dispersed R&D can only potentially enhance the value of firms' innovations, as indicated by forward citations to firms' patents, if firms pursue knowledge integration and collaboration across locations.

A large number of studies in this field have examined the factors that contribute to the explanation of foreign R&D conducted by multinational firms (e.g. Zejan, 1990; Odagiri and Yasuda, 1996; Kumar, 2001; Belderbos, 2001 & 2003; Kuemmerle, 1999; Belderbos et al., 2008). These studies have shown that foreign R&D is closely related to the extent of local manufacturing activities of the firm and often follows FDI in manufacturing with some time lag. Proximity to manufacturing is often required for applied engineering and product development in order to appropriately adapt products to local markets (e.g. Kenney and Florida, 1994). Foreign R&D is also attracted to large and sophisticated local markets with high per capita income levels. R&D in proximity to lead users helps companies to stay at the forefront of market and technological developments and to recognize and respond to changing customers' demands (Von Zedtwitz and Gassmann, 2002).

Whereas the above factors can all be related to adaptive R&D motivations, innovative R&D abroad and overseas technology sourcing are found to be related to the technological strength of host countries, the availability of scientists and engineers, and the strength of IPR protection regimes. Patel and Vega (1999) and Le Bas and Sierra (2002) examined patent portfolios of a large sample of firms and showed that in a majority of technological fields, firms tended to conduct foreign R&D in host countries that were specialized in those fields. Related findings are reported by Chung and Alcacer (2002) suggestin that technical capabilities of US states are an important determinant of manufacturing entries by foreign multinational firms. A limited number of studies that were able to differentiate between innovative and adaptive foreign R&D have shown that technology factors mainly play a role in innovative R&D decisions. Belderbos et al. (2009) found that research activities by Japanese firms responded to technological opportunities as measured by patenting growth, while development activities responded mainly to market growth. Similarly, Shimizutani and Todo (2007) found that Japanese firms' foreign research expenditures were related to host countries' total factor productivity as indicator of the level of technological development, while their development expenditures responded strongest to market size.

There are strong indications that the availability of a large pool of engineers and scientists at relatively low cost is a factor attracting R&D. Survey reports suggest that foreign R&D is driven by a lack of sufficient R&D manpower in developed home countries (e.g. Frost and Sullivan, 2004**;** Thursby and Thursby, 2006). India and China are currently seen as the most attractive locations of R&D off-shoring (UNCTAD, 2005), with cost reduction as a major motivation (Booz Allen Hamilton and INSEAD, 2006). The empirical evidence here is however still scarce (OECD, 2007).

A growing number of studies have provided evidence that strong intellectual property right regimes help to attract inward R&D. The threat of unwanted dissipation of technological knowledge abroad is large if host countries do not have an effective system of protecting ownership rights of technologies, and this may favor concentration of R&D at home. Branstetter et al. (2006) examined the impact of reforms in intellectual property rights regimes in 12 countries on R&D in foreign US affiliates. They found a positive impact of the strengthening of IPR regimes over time on inward R&D activities, specifically for multinational firms with large patent portfolios. Similar findings are reported in Belderbos et al. (2008) for foreign R&D by European multinationals within Europe. Allred and Park (2007) suggest that the positive impact of IPR on foreign R&D is conditional on a sufficient level of economic development of host countries. Zhao (2006) demonstrated that multinational firms limit the scope of their innovative activities in countries with weak IPR regimes to technologies that are only valuable if combined with other, complementary technologies that are developed in-house.

Science and (Foreign) R&D

Public research institutes and universities may influence firms' innovation activities in several ways. They supply scientists and engineers, supply consultants on expert issues, serve as collaboration partners and provide licenses on new prototypes and embryonic technologies to firms (Branstetter and Kwon, 2004; Hall et al, 2003;Cassiman et al, 2008). Revolutionary scientific discoveries can also open up completely new areas of applied research and development. Knowledge and understanding of scientific developments provides firms with a broader understanding of the technological landscape that they search to develop new inventions, and may guide them to the most promising technological directions, avoiding wasteful experimentation and raising productivity of R&D activities (Rosenberg, 1990; Fleming and Sorenson, 2004).

An expanding set of empirical studies has shown that proximity to, and involvement in, academic research, as well as formal collaborative research with academia, increases the innovative performance of firms (e.g. Jaffe, 1989; Acs et al, 1991 & 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). Zucker et al (2002) found that firms can improve their R&D productivity by collaborating with academic 'star' scientists in their fields of expertise, pointing to the crucial role of the quality of academic research. Empirical studies, mostly in the domain of regional economics, have furthermore shown that academic research stimulates the growth of industrial R&D and the set-up of new research intensive ventures in the region (e.g. Jaffe, 1989; Bania et al., 1992; Anselin et al., 1997; Zucker et al. 1998 & 2001; Abramovsky et al, 2007). Bania et al. (1992) showed that industry R&D laboratories in the US are likely to locate in metropolitan areas with university research as well as state supported science and technology programs. Zucker et al. (1998 & 2001) demonstrated that the location of new biotech enterprises is closely related to the presence of 'star' scientists, both in the US and in Japan. Abramovsky et al, 2007 found that the presence of excellent university research departments in UK regions attracted industrial R&D activities to these regions.

The benefits of academic linkages will differ across firms, as firms possess different capacities to recognize, absorb and utilize academic knowledge (Cohen and Levinthal, 1990; Gambardella, 1992; Liebeskind et al, 1996; Cockburn and Henderson, 1998; Fabrizio, 2009). Gambardella (1992) showed that firms can increase their research productivity by performing in-house scientific research, and suggested that in-house scientific capabilities allow firms to exploit external scientific knowledge more effectively. Cockburn and Henderson (1998) similarly showed that firms employing researchers that are collaborating with external academics reach higher R&D productivity levels. Employing scientists in-house (as "gatekeepers" and "boundary spanners") is important to establish a reputation in the academic world and to form a bridge with the scientific world. Similarly, Liebeskind et al (1996) uncovered that companies in the biotech sector that were engaged in joint research and publishing with academic institutions were more effective at externally sourcing new scientific knowledge. Effectively drawing on the science base seems not costless but conditional on human capital within the firm as well as on the adoption of adequate organizational practices (Cockburn and Henderson, 1998; Cockburn et al., 1999). The value of academic research is greater for firms that have organized their R&D activities in such a way that they can draw on, and benefit from, scientific developments. Hence, firms with a more outspoken science orientation of R&D activities are also likely to attach greater value to academic research in their international R&D strategies.

Despite the demonstrated importance of academic science linkages for industrial R&D, studies of foreign R&D by multinational firms have given little attention to the role of host countries' scientific strengths. There is some prima facie evidence that this role is important, as the strength of local universities, and opportunities to collaborate with academia, rank high as factors determining the attractiveness of future foreign R&D locations in surveys of multinational firms (Thursby and Thursby, 2006). In addition, Florida (1997) reported that more than two-thirds of foreign-affiliated R&D laboratories in the US were collaborating with US universities. Only a handful of empirical studies have examined the relationship between public research and foreign R&D, but have done so at an aggregate level (country/region) or in a single country setting. Cantwell and Piscitello (2005) found a positive relationship between public R&D employment and the aggregate R&D activities of foreign controlled firms across European regions. Hegde and Hicks (2008) found a positive correlation between industry aggregates of US foreign R&D and science and engineering publications of host countries. Alcacer and Chung (2007) found a positive influence of the presence of local university research on foreign firms' propensity to invest into US regions, but their analysis was concerned with manufacturing investments rather than R&D activities (on which we focus in this paper).

Although there are indications that academic research matters for R&D location decisions of multinationals, the relative importance of this factor in attracting foreign R&D, as compared to the wide range of other host country factors, has not been uncovered in prior work. This paper addresses this question by examining the propensity to conduct R&D abroad in 40 host countries by 176 of the largest R&D spending European, American and Japanese firms. We examine foreign R&D decisions at the micro level, using firm level data at the level of technology fields (30 fields) in two periods, 1995-1998 and 1999-2002. Furthermore, we explore to what extent there is firm heterogeneity in the responsiveness to countries' academic research strengths, depending on the science orientation of firms' R&D activities. Our key prediction is that countries' academic research strengths do attract foreign R&D investments of firms with a high scientific orientation in their R&D activities.

DATA

In order to investigate R&D internationalization decisions of multinational firms, we collected data on the location of technological activities of 176 high-technology firms over the periods 1995-1998 and 1999-2002. The firms are high R&D spenders in their sectors and are roughly equally divided over home regions (Japan, Europe and US) and five industries (Engineering & General Machinery, Pharmaceuticals & Biotechnology, Chemicals, IT Hardware and Electronics & Electrical Machinery).

The ‘2004 EU Industrial R&D Investment Scoreboard’ was used to identify the firms. The 176 firms were responsible for roughly 30 percent of the European patent applications during the 1995-2002 period and spent an average 644 million US dollar on R&D in 2002. The smallest yearly R&D budget amounted to 21 million dollars (Vaisala), and the largest reaches almost 6 billion dollars (Pfizer).

Patent application data are used as indicator of firms’ R&D activities and their location. Patent data have the advantage of being easy to access, covering long time series and containing detailed information on the technological content, owners and inventors of patented inventions. They also have shortcomings: not all inventions are patented, patent propensities vary across industries and firms, and patented inventions differ in quality (Basberg, 1987; Griliches, 1990). Given the novelty requirement for patents, patent-based indicators of foreign R&D are perhaps more likely to represent foreign research activities than foreign development activities directed at local adaptation. Despite the drawbacks, patents are extensively used as indicator of foreign inventive activities (Patel and Vega, 1999; Belderbos, 2001; Guellec and Van Pottelsberghe, 2001; Le Bas and Sierra, 2002; Cantwell and Piscitello, 2005; Branstetter and Kwon, 2004; Allred and Park, 2007), given that systematic data (certainly at the firm level) on R&D expenditures by location are either not collected or not generally available for analysis. In this study we draw on patent data from the European Patent Office (EPO). Due to long time spans of patent granting decisions at the European patent office (4-6 years) the use of patent application data has clear advantages over grants as a source of information on the location of recent technological activities. They can be considered a better indicator of the presence of foreign R&D activities than patent grants, as the latter exclude R&D efforts and inventions that do not result in grants.

We constructed patent datasets of firms at the consolidated level, i.e. all patents of the parent firm and its consolidated (majority-owned) subsidiaries are retrieved. For this purpose, yearly lists of consolidated subsidiaries included in corporate annual reports, yearly 10-K reports filed with the SEC in the US and, for Japanese firms, information on foreign subsidiaries published by Toyo Keizai in the yearly ‘Directories of Japanese Overseas Investments’ were used. The consolidation was conducted on a yearly basis to take into account changes in the group structure of the sample firms due to acquisitions, mergers, green-field investments and spin-offs. Using consolidated patent data is crucial to study foreign inventive activities since foreign patents may be applied for under the name of a foreign legal entity rather than under the parent firm name. On average 18 percent of the firms' patents were filed under a subsidiary name or other name variants. We use address information of the patent inventors to determine the country of origin of patented inventions, assuming that inventors live in the vicinity of their workplace. Inventor addresses give a much more accurate indication of patents' geographic origin than company addresses as firms tend to use the headquarter address instead of the address of the subsidiary or unit where the invention originated as assignee address (Deyle and Grupp, 2005). If a patent lists multiple inventors based in more than one country, we assigned the patent to each country. Finally, patents are assigned to technology fields based on their IPC technology codes and a technology concordance table that links each 8 digit-IPC code (+-64000) to one of 30 technology fields. The concordance table has been jointly elaborated by Fraunhofer-Gesellschaft-ISI, Institut National de La Propriété Industrielle (INPI) and Observatoire de Sciences et des Techniques (OST) and combines IPC classes that represent similar technical function or application in broader technology classes. When a patent is assigned to different technology fields, it is counted in each field.

We examine the location of R&D activities of 176 high-technology firms in 40 host countries. Two criteria are used to select host countries: (i) they record a minimum level of technological activity (50 patents) over the period 1995-2002 and (ii) data on country level regressors (e.g. IPR protection, engineering wage) is available. The list of 40 host countries includes all major developed countries and the largest developing economies in South-East Asia and South-America, plus South Africa.

Insert Table 1 about here

The distribution of patent applications by European, US and Japanese firms over host countries during the period 1995-2002 is shown in Table 1. The numbers in this table are aggregates over all 30 technology fields. US firms in the sample conduct on average 24 percent of their R&D abroad. This percentage is higher for European firms at 39 percent, but most of European firms' foreign R&D activities are undertaken within Europe (24 percent), with the share of R&D activities outside Europe limited to 15 percent. Much lower R&D internationalization levels (smaller than 8 percent) are recorded for Japanese firms. These numbers are comparable to foreign R&D shares found in prior studies (Edler et al, 2002; Von Zedwitz & Gassmann, 2002; OECD, 2007). By country of location, the figures show a concentration of US firms' foreign R&D in Europe, and similarly European firms' foreign R&D is concentrated in the US. Most of Japan's foreign R&D is (approximately evenly) spread over the US and Europe. Within Europe, large countries (France, Germany, and United Kingdom) and some smaller economies (Belgium, Netherlands, Switzerland and Sweden) show substantial foreign owned R&D activities. Asian countries host only a small amount of the sample firms' foreign R&D activities (1-2 percent). Among Asian countries, Japan, China, Singapore and Israel (mainly for US firms) attract most foreign R&D. There is almost no inward R&D in South-American countries, with Brazil as notable exception. Finally, around 1 - 1.5 percent of firms' R&D activities are undertaken in Canada and Australia. A breakdown of foreign R&D activities over the two 4 year sub periods (not in table 1), indicates an increase over time in the share of foreign R&D by Japanese firms (from 6.9 to 8.2 percent) and US firms (from 22.7 to 24.7 percent), while the share of foreign R&D for European firms remains constant at 39 percent.

EMPIRICAL MODEL AND VARIABLES

Dependent Variable and Empirical Model

The dependent variable in our analysis is a binary variable taking the value one if a firm has applied for a patent in a technology field, where the inventive activity took place in a host country. If this variable takes the value one, this is evidence that the firm conducts R&D in that host country and technology field. We analyze foreign R&D at the level of 30 technologies as firm' and countries' strengths differ strongly across technological activities (e.g. Patel and Pavitt, 1991; Patel and Vega, 1999;

Cantwell and Piscitello, 2005, Belderbos et al. 2008), while countries' academic research strengths also vary by academic disciplines related to different technology fields. We will examine the robustness of this technology-specific approach by estimating a model in which firms' patents are aggregated across fields at the country level.

Only host countries with existing patenting activity in a technology field are considered as potential locations for R&D in the given technology field. Similarly, foreign R&D location decisions are only analyzed in technology fields in which the firms have existing R&D activities. Given that the firms are often active in multiple technology fields and that a range of 40 host countries can be considered as potential locations, this leads to a large dataset containing 87089 observations in the first period and 100326 in the second period. Among these observations, the number of nonzero cases is relatively small: 4.2 percent and 5.0 percent of observations are positive in period 1 and 2 respectively**.** The distribution of the count of the number of host country-originating patent applications by the 176 multinational firms is highly skewed, as in addition most positive patent cases are small numbers. Of the positive firm-technology-host country patent counts, 1 patent cases constitute 45 percent, 2 patent cases another 16 percent, while more than 10 patents are reported in only 12 percent of cases. Hence, most of the variation across firms in the pattern of foreign R&D is in the decision to conduct R&D activities abroad or not, and there is little variation among the positive R&D cases. Count data models are sensitive to the observations on the few firms with substantial patenting activities in a host country and technology. Some of these cases are likely to be more idiosyncratic and due to historical circumstances and international mergers**.**[2] In order to make our results more representative of all sample firms, our preferred focus is on the binary variable. Hence we estimate the probability that firms conduct some R&D abroad in relevant technology fields. For comparison, we also estimate count data models and report on these at the end of the empirical results section.

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[2] Firms experiencing a dramatic change in international activities due to a large international merger in one of the periods (e.g. Astra–Zeneca) were omitted from the analysis. Firms with more than one apparent 'home country' (such as ABB or STMicroelectronics) were assigned to one home country and R&D activity in the second home country was excluded from the analysis.

We aggregated patents counts over 4-year periods, 1995-1998 and 1999-2002. This aggregation allows us to match the indicator of R&D activity to a number of host country variables that are not available on a yearly basis (such as the information on wages of scientists and engineers). It also ensures a greater number of positive observations at the technology-disaggregated level of analysis compared with an annual analysis. The 4 year period allows us to identify a larger number of R&D locations and laboratories, which may not patent on a yearly basis. Furthermore, estimation of models for two individual periods allows us to examine possible changes in the determinants of foreign R&D and the potentially changing role of academic research.

Given the binary nature of our dependent variable, a Logit model is used to examine the impact of firm and host country characteristics (including host countries' academic research strengths) on the probability that a firm conducts foreign R&D in a host country and technology domain. We cluster error terms at the firm level in each model in order to control for correlations in error terms due to unobserved firm characteristics. All explanatory variables are measured prior to the 4 year periods. We note the possibility that R&D location decisions leading to patent activity in the period may have been taken earlier based on firm and host country characteristics not captured in the empirical model. Although firms are likely to adjust their R&D organization and locations if environmental factors are no longer favorable, (Nachum et al., 2008), our results may suffer from this omitted variable bias. In one of the sensitivity tests reported in the empirical results section, we will control for this residual unobserved heterogeneity by including the count in t-1 of firm patents in the technology and host country.

Academic Research Strength

We use information on scientific articles authored by residents of a country and published in peer reviewed journals recorded in the 'Web of Science' s to assess the academic research strengths of each country at the level of broad technological fields. Publications are extracted from yearly updates of the 'Web of Science' database of Thomson Scientific and only papers of the document type article, letter, note and review have been selected. Using locations of publishing institutions and the ISI science classification table, publication numbers are available at the level of countries and 240 scientific disciplines. To construct an indicator that is technology field specific, all 'exact science' disciplines were linked to technology fields based on descriptions of the science and technology fields. To avoid misallocations, science fields were linked to five broad main technology classes rather than the 30 (sub)technology classes.[3] Appendix 1 contains a list of the 30 technology subclasses and 5 main technology classes. 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 can be considered a relatively accurate measure of the output of qualitative academic research at the level of countries and broad technology classes. Preferably we would have restricted this variable to publications assigned to public research institutions and universities, omitting publications (co-)assigned to firms. Given the large number of publications counted (close to 10 million), parsing of firm publications would be an extremely labor intensive data exercise. Previous work on smaller samples of publications has however suggested that the share of publications authored by firm researchers is small. In the biotechnology field, where firms are most active in scientific research, this share, including papers co-authored with academia, does not surpass 3 percent (Fabrizio, 2009; Furman et al, 2006). In general, there is only a marginal feedback effect of industrial research on the direction of university research (Furman and MacGarvie, 2007).

Insert Table 2 about here

Publication numbers aggregated over two periods (1995-2002) are presented in Table 2. The last column contains total country publication numbers in all 'exact science' disciplines. These numbers can be higher than the sums of the technology class specific numbers (columns 2 to 6) due to the multidisciplinary nature of some science fields (multiple allocations to main technology classes).

[3] In most cases a scientific discipline could be uniquely linked to one technology class (e.g. Virology to Chemistry & Pharmacy). When this was not the case, the scientific field was classified in all relevant technology classes (e.g. Applied Physics to Electrical Engineering, Instruments, Process Engineering & Special Equipment and Mechanical Engineering and Machinery). The science-technology concordance table is available from the authors upon request.

Residents in the 40 host countries published between 1995 and 2002 more than 10 million articles in ‘exact science’ disciplines. The US is the largest contributor (>3 million), followed by Japan (950’000) and large European countries: United Kingdom (830’000), Germany (765’000) and France (570’000). Asian countries (apart from Japan) account for 1.3 million publications, with the majority coming from Russia (300’000), China (280’000) and India (200’000). The distribution of publications over technology classes shows that ‘Chemistry and Pharmaceuticals’ is by far the largest field (59%), followed by ‘Process Engineering and Special Equipment’ (19%), ‘Mechanical Engineering and Machinery’ (12%), ‘Electrical Engineering’ (10%) and ‘Instruments’ (10%). The distribution over technology classes is not uniform across host countries. The US and most European countries have a similar specialization profile, with a strong focus on publishing in ‘Chemistry and Pharmaceuticals’. On the other hand, Asian countries (including to a lesser extent Japan) are relatively more specialized in the engineering disciplines. A similar focus on engineering disciplines is present in some European countries such as Poland, Portugal and Greece. We expect that host countries’ academic research strengths as indicated by such field-specific publication counts attract multinational firms’ R&D investments. We measure academic research strength as the number of publications of host country residents in the relevant technology classes in t-1.

Other Host Country Characteristics

A reliable estimate of the role of countries’ academic research strengths in attracting foreign R&D requires the inclusion of other host country variables that are expected to impact on foreign R&D decisions. We include a broad set of host country factors that have been found to be relevant in previous empirical work in our analyses. We include the host country’s *technological strength* in a field, measured by the number of patent applications originating in the host country in the technology field (30 classes). Patents of the focal firm are subtracted from these counts. Since R&D activities do not only rely on knowledge generated in the narrow technological field, we also control for the country’s technological strength in other technology fields within the same main technology class (five broad technology classes). Further, the analysis takes into account the host country’s level of *IPR protection*, by inclusion of the IPR index from the Global Competitiveness Report published by the World Economic Forum. This index is constructed based on the opinions of multinational firms and experts on the strength of patent, trademarks and copyright protection; it takes values between 0-10, with high scores for intellectual property right systems that are highly aligned with international standards.[4] IPR data are available for the years 1995 (period 1995-1998) and 2000 (period 1999-2002). Both technological strength and IPR protection are expected to have a positive effect on multinational firms' R&D investments. Countries with large and sophisticated markets, measured respectively by *market size* and *GDP per capita* levels, should also attract more foreign R&D. Market size is measured at the sector level and is defined as the sum of host country production and imports minus exports in the sample firm's main industry. Data are drawn from OECD STAN and UNIDO industrial yearbook data.

The likelihood that a host country attracts international R&D will also be related to the geographic and language distance between the host and home country of the investing MNE, as the cost of R&D coordination and doing business abroad rises with distance (e.g. Belderbos et al, 2008; Nobel and Birkinshaw, 1998). *Geographic distance* is measured in kilometers between the capital cities of both countries. *Language similarity* is a dummy variable that takes the value 1 if both countries share at least one official language. The wage costs of R&D personnel in the country is also expected to affect its attractiveness for inward R&D. Yearly gross income levels of engineers are taken as indicator of these wage costs. Data are taken from the UBS 'Price and Earnings' reports, with 1994 wage levels assigned to period 1995-1998 and 1997 wage levels assigned to 1999-2002, as earnings reports are not available on a yearly basis. Finally, a dummy variable for *European host country* is added to control for the possibility of a patent bias in our data: firms may be more likely to choose EPO to apply for patent protection on inventions if these inventions originate in Europe.

[4] Use of the patent protection index due to Park and Wagh (2002) gives qualitatively similar results.

Firm Scientific Orientation

The presence of relevant academic research in host countries is expected to have a larger impact on R&D decisions of firms with a more pronounced *science orientation* in their research activities, as these firms are likely to possess the absorptive capacity to benefit from science connections. The extent to which firms draw on academic knowledge depends partly on their technological focus, but also varies across firms active within similar technology fields. We measure a firm's scientific orientation through references to scientific literature in firms' prior patents. Surveys of patent inventors (Tijssen, 2001; Fleming and Sorenson, 2004) have shown that inventors are aware of a significant part of the scientific papers cited in their patents, qualifying scientific non-patent references as indicators of the 'usage' of science by firms in their R&D activities (Branstetter & Kwon, 2004; Fleming and Sorenson, 2004). Patents cite a variety of non-patent literature (journals, books, newspapers, company reports, industry related documents etc.) which do not all refer to scientific sources (Harhoff et al, 2003; Callaert et al, 2006). In line with Fleming and Sorenson (2004) and Cassiman et al (2008), we only consider non-patent references to scientific journals listed in the Web of Science database as scientific references. We identified scientific non-patent references by using an elaborate algorithm to link non-patent references to ISI Web of Science journals.[5] Our sample firms made 72115 references to non-patent literature in their 3 year patent portfolios. Around half (51,7%) of these non-patent references cited Web of Science journals and were classified as scientific references. This number is comparable to those reported in prior studies on the nature of non-patent references (Narin and Noma, 1985; Van Vianen et al, 1990; Harhoff et al, 2003; Callaert et al, 2006). The variable *firm science orientation* is the average number of scientific references per patent in the firm's three year prior patent portfolio. The sample firms cited, on average, 0.2 scientific references per patent, with values ranging from 0 to 2.5. The extent to which firms draw on scientific knowledge differs across industries but also varies substantially across firms within the same industry. Science orientation is, on average, highest for pharmaceuticals (average of 0.5) followed by the

[5] We have used a list containing all journals (10216) in the SCI between 1973 to 2006 and in the SSCI from 1986 to 2006.

IT sector (average of 0.2), electronics (average of 0.13), and chemicals (average of 0.12), and the lowest for non-electrical machinery (average of 0.05) At the same time, there are firms lacking a science orientation (zero references) in all industries, while in each industry there are firms with high science orientation values (0.4 - 0.6). We will examine the consequences of this firm heterogeneity for the impact of academic research strength on R&D location decisions.

To test whether science-oriented firms are more attracted by host country academic excellence, the interaction variable between host country academic strength and firm scientific orientation is included in the analyses. We expect a positive sign for the interaction effect. To examine the moderating effect of science orientation on academic research strength, however, we cannot solely rely on the value and significance of the interaction coefficient, but we have to calculate the partial cross-derivative of the Logit probability with respect to academic research and firm scientific orientation, and check its significance across sample observations (e.g. Ai and Norton, 2003). In addition to the interaction effect analyses, we will also present the results of split sample tests in which all covariates are allowed to vary between firms with above and below median scientific orientation.

Other Firm Characteristics

The extent to which MNEs internationalize their R&D activities in a field will also depend on their overall technological strengths and the size of their R&D activities in the field (Song and Shin, 2008). We include the variable *technological strength*, the number of patent applications by the firm in the technology field, and expect a positive impact. We also include the firm's total number of patent applications (*total patents*) to examine the impact of the overall size of R&D activities of the firm on foreign R&D. Foreign R&D activities in a host country are more likely when firms have manufacturing or sales operations in the country, as manufacturing and sales operations call for product and process adaptations and adaptive R&D. We include a dummy variable (*manufacturing/sales subsidiaries in host country*) which takes value 1 if a firm has at least one manufacturing or sales subsidiary in the host country. We draw on data from the early 'Directories of Japanese Overseas Investments' published by

Toyo Keizai for Japanese firms, and corporate annual reports and company websites for European and US firms. We control for firms' experience in international R&D to take into account that effective R&D internationalization tends to be a gradual process of building capabilities and experiential learning (e.g. Belderbos, 2003). *R&D experience* is the number of years since the firm reported its first foreign based invention in a patent application (evaluated in the years 1994 and 1998, respectively for the two periods under consideration). We further control for the *age of the firm*, as younger firms may lack experience and managerial resources to facilitate the establishment of foreign R&D activities. Finally, we include country of origin dummies (with the US as reference group) and technology field dummies (electrical machinery as reference group). All continuous variables are taken in natural logarithms. Except for countries' engineering wages, IPR protection levels, and science orientation, one year lagged values (1994 and 1998) are taken for all explanatory variables. Definitions and summary statistics for the dependent and independent variables are provided in Table 3 and a correlation table is provided in Appendix 2.

Insert Table 3 about here

EMPIRICAL RESULTS

The results of the Logit models relating the probability of firms to conduct R&D in a host country and technology field to host country and firm characteristics are presented in Table 4. Models 1 show the results of regressions without the interaction of countries' academic research strength and firms' science orientation; models 2 add this interaction effect. Each model is estimated for two periods: 1995-1998 and 1999-2002; LR tests reject the hypothesis that the coefficients are identical across both periods. All models perform rather well. They are highly significant with the McFadden pseudo R-squared values between 38 and 40 percent. The rate of correct predictions (evaluated with the mean sample probability as benchmark) is close to 86 percent for positive values (sensitivity) and close to 83 percent for the zero values (selectivity). Hence, the models perform equally well in predicting the occurrence of foreign R&D as in predicting the absence of foreign R&D. An alternative aggregate indicator of predictive power proposed by Hosmer and Lemeshow (2000) that takes into account both sensitivity and selectivity similarly suggests a very satisfactory ability to discriminate between the two outcomes.[6]

Insert Table 4 about here

In period 1, academic research has a positive and significant coefficient in model 1, confirming that multinational firms take the strength of nations' relevant academic research capabilities into account in their R&D internationalization decisions. Results for the second period (1999-2002) are comparable. The estimated coefficient for academic research in model 1 is slightly smaller in period 2, but a two-sided Wald test (Clogg et al., 1995) could not reject the null hypothesis of equality of coefficients at the 10 percent significance level. In Model 2, the interaction effect of firm scientific orientation and host country academic research strength is added, in addition to the main effect of firm scientific orientation. The LR tests show that the fit of model 2 significantly improves on model 1 both in period 1 and period 2. Inclusion of the science orientation variable and its interaction term leaves the impact of the other explanatory variables largely unchanged. The interaction variable itself is positive as expected, and significant, while the coefficient of host countries' academic research strength becomes smaller but remains significant as well. In period 2, the moderating impact of firm science orientation is larger (a coefficient of 0.53 versus 0.32) while the main effect of academic research strength is smaller 0.13 versus 0.19). The firm science orientation variable has a negative coefficient and is significant in period 1. The scale intensive nature of science-intensive technology development is likely to favor geographic concentration of major R&D activities, and such concentration usually takes place in the home laboratory

[6] The 'ROC' indicator of Hosmer and Lemeshow (2000) examines the rate of correct prediction of occurrence and non-occurrence for the entire range of possible cutoff points. Our models score 0.92 on a range of 0-1 by this measure, which is qualified as 'outstanding'.

(Kuemmerle, 1998). This is consistent with the observation that firms in science oriented industries often have lower shares of R&D conducted abroad (Patel and Vega, 1999; OECD, 2007).

In non-linear models, such as the Logit model, the sign and significance of the interaction variable is no definitive indication of the sign and significance of the moderating influence the interacted variables have on each other. The moderating effect of firms' scientific orientation on the role of host countries' academic research strengths in attracting foreign R&D is given by derivative of the marginal effect of academic research on the probability to conduct foreign R&D with respect to firms' scientific orientation (Ai and Norton, 2003; Hoetker, 2007). This cross-derivative is a more complex expression including the estimated coefficient of the interaction term, the coefficients of the main effects, and the predicted probability. Since the coefficients of the main and interaction variables take different signs in our model, the cross-derivative can switch sign across observations. We calculated the value and standard error (and implied z-statistic) of the cross-derivative for all sample observations. In period 1, the cross-derivative takes positive values for more than 90 percent of sample observations, while it is negative and significant for only 0.4 percent of the observations. Of the observations with a positive cross-derivative, a little less than 19 percent is significant. In period 2, the cross-derivative takes positive values for an overwhelming 98.5 percent of sample observations, while it is significant in 84.9 percent of the cases. The results confirm that firms with a greater science orientation in their research activities give more weight to countries' academic research capabilities when deciding on foreign R&D locations. The effect is particularly pronounced in the most recent period.

The other host country variables have the expected signs and are in almost all cases significant. In period 1, host country's technological strength in the field and related fields, the degree of IPR protection, sector market size, and GDP per capita all have significantly positive estimated coefficients, while engineering wage costs has a negative and significant coefficient. The significant coefficients of language similarity and geographic distance show that firms are more likely to conduct foreign R&D in countries that are geographically close and share a similar language with their home country. Among the firm-level control variables, firm's technological strength in the relevant field is an important driver. Firms are also more likely to conduct foreign R&D in countries in which they operate manufacturing or sales subsidiaries and if they have more experience in performing international R&D operations. The country of origin dummies show that Japanese firms, ceteris paribus, have a lower propensity to internationalize R&D compared to US firms, while firms based in Sweden, Finland, and Switzerland have a significantly greater propensity. The main difference in the results for period 2 is a strong decline in the coefficient of GDP per capita, with the coefficient becoming insignificant in the 1999-2002 period. In general, a pattern is visible of a reduced coefficients for market and manufacturing related variables (GDP per capita, sector market size, manufacturing/sales subsidiary) associated with adaptive R&D. Technology related factors, such as technological strength in the field and related fields, IPR protection, in addition to wage costs, appear to gain in importance.

The magnitude of the impact of host country variables can be judged by calculating elasticities, evaluated at mean regressor values. The elasticity of the probability to engage in foreign R&D with respect to a logarithmic transformed explanatory variable in a Logit model equals to $(1-P)*\beta_j$, i.e. the product of the estimated variable coefficient and 1 minus the event probability. As P is low for our models, the elasticities are almost identical to the estimated coefficients. If we compare elasticities across host country variables, the impact of countries' academic research strength on foreign R&D can be considered as substantial. The elasticity of the probability of conducting R&D with respect to academic strength varies between 21 and 24 percent for both periods. This effect is smaller than the impact of countries' technological strength (40-42 percent), and wage costs (35-45 percent), but is higher than the impact of market size (11-13 percent), technological strengths in related fields (11-12 percent) and GDP per capita in the second period.

Insert Figures 1 and 2 about here

The moderating effect of firms' scientific orientation on the impact of host countries' academic research strengths on the probability to conduct R&D is further illustrated in figures 1 and 2. The figures depict mean predicted probabilities of Model 2 calculated over all observations in the sample for each period, for varying values of academic research strength and three values of firm science orientation. The figures illustrate how the increase in the probability to conduct R&D in a host country as a function of host country academic research capabilities depends on firms' science orientation. In period 2 this is most pronounced. For firms with a low (mean minus two standard deviations) science orientation, the probability of foreign R&D increases from 2 to 5.5 percent over the range of lowest to highest academic research strength. For firms with a high (mean plus two standard deviations) science orientation, the probability to engage in foreign local R&D is close to zero in host countries with low academic research strengths, but this probability increases to almost 9 percent for countries with the highest academic research strength. In period 1, these patterns are similar, though less outspoken.

Robustness Checks and Alternative Specifications

We explore the robustness of the empirical results by estimating a range of alternative specifications. First, we examined the sensitivity of our results to an alternative method of allowing for firm heterogeneity. Instead of including a single interaction effect between science orientation and academic research strength, we conducted a split sample test at the median value of firm science intensity[7]. This allows all covariates to differ between firms with high and low science orientation (Hoetker, 2007, Alcacer and Chung, 2007). The results are presented in Table 5. Academic research strength is positive and significant for above median science orientated firms, with elasticities ranging between 41 and 44 percent for both periods, while for below-median science orientated firms no significant effect is found. A two-sided Wald test (Clogg et al, 1995) rejected the null hypothesis of equality of coefficients of the academic research strength variable in the subsamples with low and high science oriented firms at the 5 percent level. These results again provide strong confirmation that host countries with strong academic research are attractive to firms with a sufficient science orientation in their R&D. Among the other covariates, there appear few other systematic differences between the two groups

[7] The median value of firms' scientific orientation is 0.16 for period 1 and 0.11 for period 2.

of firms, except for the fact that high science oriented firms put more weight on countries' IPR protection levels in their R&D internationalization decisions. Among less science oriented firms, younger firms are more likely to invest in R&D abroad compared to older firms.

Insert Table 5 about here

Second, we examined the robustness of the empirical results to a specification in which the dependent variable is the *number* of patents of the firm in a technology field originating in the host country. Results of a negative binomial regression analysis of this count variable are reported in Table 6. In period 1, the main effect of academic research strength is positive and significant, while the moderating impact of science orientation is insignificant. In period 2, it is the moderating impact of science orientation which is highly significant, while the main effect of academic research strength is insignificantly different from zero. Overall, these results are in accordance with our preferred Logit specification, although it appears more difficult to obtain precise parameter estimates for the count model. The results suggest that the moderating impact of science orientation is more important in the most recent period. As the elasticity of a logarithmic transformed variable in a Negative Binomial Count model equals the estimated variable coefficient (Wooldridge, 2002), we conclude that the elasticity of R&D with respect to academic research strength is slightly higher in the Negative Binomial model in period 1 (26 percent) than in the corresponding Logit model.

Insert Table 6 about here

In a third robustness check, we added the lagged dependent variable 'prior R&D' to the model: a dummy variable indicating whether the firm had R&D operations in the host country and technology in the year before the period of analysis. This variable will correct for any residual firm and host country unobserved heterogeneity in foreign R&D investments decisions prior to the period of analysis. On the other hand, inclusion of a lagged dependent variable leads to a downward bias in host country coefficients when countries have stable characteristics over time. The empirical results, reported in Table 7, are largely robust. As expected, prior R&D in the host country, as discerned from patent applications, has a positive and highly significant influence on the presence of R&D activities in the period of analysis. In period 1 the coefficient of academic research strength is slightly reduced to 0.17. In period 2, it is the interaction coefficient between academic research strength and science orientation that is highly significant, again with a somewhat reduced coefficient.

Insert Table 7 about here

Fourth, we investigated a possible alternative hypothesis with respect to heterogeneous responses by firms to countries' academic research strengths. In an analysis of foreign manufacturing investment locations in the US, Alcacer and Chung (2007) found that technological leaders respond stronger to academic research strengths than technologically lagging firms. Leading firms are likely to have a greater absorptive capacity for academic research and at the same time they may be less attracted to locations with industrial R&D due to concerns about spillovers and appropriability. Technologically leading firms have also been found to be more sensitive to IPR protection in their foreign R&D decisions (Belderbos et al., 2008; Branstetter et al., 2006) and to pursue R&D internationalization most aggressively (Berry, 2006). We examined such potential systematic differences in the drivers of R&D location decisions between technology leaders and laggards by performing a split sample test at the median worldwide share of patents of the firm in the respective technology class. The results are reported in Table 8. The findings show that the impact of academic research strength is greater for technology leaders, with coefficients of the main and interaction effects being larger for the technology leader subsample. On the other hand, the interaction effect is still significant (at the 10 percent level) for technology laggards in period 2. The cross derivative results suggest that this moderating impact is positive throughout and reaches significant in the majority of observations. Hence, academic research strength can attract technology laggards if these have a sufficient absorptive capacity as reflected in the science orientation in their research. We conclude that technological strength and science orientation are both characteristics that differentiate firms in their attraction to academic research strengths, but that technological strength is not a necessary condition. Among the other variables, IPR protection has a greater coefficient for technology leaders as expected, and this difference is large in period 2. Technology laggards are more responsive to wage costs and market conditions (GDP per capita) which may indicate a greater focus on low-cost development strategies rather than research-based strategies for competiveness. In contrast to Alcacer and Chung (2007), we do not find any substantial difference for leaders and laggards in the impact of countries' technological strength as indicator of industrial research activity. This may be partly related to the country level data used in the current study, while potential technology spillovers due to collocation are preferably analyzed at the regional level.

Insert Table 8 about here

Fifth and finally, we examined the robustness of the empirical results with respect to the level of aggregation. One may be concerned that the large number of observations in the model in relationship with the small share of positive values (4-5 percent), introduces a bias in the Logit coefficients (and estimated probabilities) due to the 'rare' event nature of the dependent variable (King and Zeng, 2001). Result of rare events Logit models on the probability to conduct R&D abroad were quasi-identical to the Logit results[8], which is likely related to the large number of observations in our Logit models mitigating a rare events bias (King and Zeng, 2001). As a further robustness check, we aggregated observations over technology fields to examine the propensity to conduct foreign R&D at the more aggregate firm and host country level. This increased the share of positive foreign R&D cases to 18 percent of a total of 13208 observations. Estimation of our models at the aggregate level alleviates the concern that the large number

[8] Rare Events Logit results are not reported in this paper because of the high similarity with Logit results in Table 4. These results can be obtained from the authors by request.

of observations in the technology level models increases the risk of Type I errors. The results, reported in Table 9, are highly consistent with the results reported in Table 4. The positive impact of academic research strengths (both main and interaction effects) are confirmed. Standard errors of some country variables have increased, which is to be expected by the substantial reduction in observations and the greater impact of collinearity of host country characteristics at the aggregate level. In particular, the aggregate analysis complicates disentangling the impact of wage costs of scientists and engineers and the impact of GDP per capita, the two variables that are most strongly correlated.

Insert Table 9 about here

CONCLUSION AND DISCUSSION

In this paper we have empirically examined to what extent the quantity and quality of academic research of (potential) host countries affects the propensity of multinational firms to conduct R&D in these countries. We also explored whether there is firm heterogeneity in the value attached to countries' relevant academic research activities, as firms possess different capacities to recognize, absorb and utilize academic knowledge, depending on the degree of science orientation in their research activities. We examined the propensity to conduct R&D abroad of 176 leading R&D intensive European, American and Japanese firms in 40 host countries and 30 technology fields. We examined the location of their R&D activities as derived from inventor locations on (EPO) patent documents in the periods 1995-1998 and 1999-2002. We measure the strength of academic research in host countries by technological fields, drawing on ISI publication counts per science field. The science orientation of firms' research activities is measured as the average number of scientific non-patent references listed on the firms' prior patent grants.

We find that the probability to conduct R&D abroad by firms is positively affected by host countries' academic research capabilities, after controlling for a broad set of other host country characteristics that attract or discourage inward R&D. The magnitude of the impact of academic strength is, with an elasticity of 21-24 percent, higher than country characteristics such as market size and GDP per capita. We also find proof for substantial firm heterogeneity in the importance of academic research for R&D internationalization decisions. Firms with a stronger science orientation in their R&D activities respond significantly stronger to host country academic research strengths. In host countries with low academic research capabilities, the probability that science oriented firms will conduct R&D is close to zero as scale and scope economies appear to favor concentration of science oriented R&D at home. In contrast, science oriented firms show the highest propensities to conduct R&D abroad in host countries with the strongest academic record. This pattern appears most pronounced in the most recent period 1999-2002.

These results were robust across a large number of specifications: in negative binomial count models, split sample tests rather than interaction variable tests, models with lagged dependent variables, aggregate (firm) level analysis rather than more fine-grained firm- and technology-level analysis, and distinguishing between technology leading firms and technology lagging firms. With respect to the last issue, we find that firms that are leading in a technology field are attracted to academic research strengths, but much more strongly so if they are science oriented; while technologically lagging firms with a high science orientation may still be attracted to academic research. Overall, our results confirm the importance of taking into account relevant aspects of firm heterogeneity when analyzing R&D location decisions (Alcacer and Chung, 2007; Nachum et al, 2008).

The analysis uncovered a number of other country factors with a significant impact on attracting foreign R&D: host country's technological strength, technological strength in related fields, market size, GDP per capita, the strength of the host country' intellectual property rights regime, engineering wage costs, geographic proximity to, and sharing an official language with the home country of the multinational. At the firm level, the firm's strength in the technological field, the overall patent strength of the firm, and a firm's prior manufacturing and sales subsidiaries in a country affect the propensity to conduct R&D abroad. Comparison of the estimated models between the two periods showed limited structural changes in the determinants of foreign R&D, but the results do indicate a weakening of market related factors in foreign R&D and a strengthening of technology and cost factors, in the second period.

The empirical results suggest that policies to strengthen university research can be effective in attracting R&D investments by multinational firms. We emphasize, however, that the results should not be taken to suggest that publication output itself is creating this attraction to foreign firms' R&D. Rather the presence of a critical mass of quality academic research, as indicated by publication output in peer reviewed journals, proxies for opportunities of firms to link up to local scientific networks of university researchers, collaborate with university research groups and university spinoffs, or hire capable doctoral researchers from these universities. Further research should disentangle the mechanisms of industry science linkages and the university characteristics that are most effective in attracting foreign multinational R&D. These may be entrepreneurial orientation (licensing, university spinoffs), or the intensity of industry science collaboration and interactions in local research networks. This type of analysis will necessitate a spatially disaggregated analysis at the regional or state level, to take into account that spillovers from science to industry are a positive function of geographic proximity (Jaffe, 1989; Anselin et al, 1997). Our study used countries as the demarcation of location decisions. This is natural starting point from a global R&D allocation perspective. Future work could conduct analyses at a more fine grained level, such as NUTS levels in the EU and state or MSA levels in the US (Alcacer and Chung, 1997; Alcacer, 2007; Furman et al, 2006). Combining global R&D decisions with more fine grained regional location characteristics is a fruitful avenue for future research. Extension of analysis to a more recent period as more recent patent data become available can uncover if the trend toward increasing importance of academic research for foreign R&D decisions and the role of firms' science orientation is continuing.

Another line of future research related to limitations of our current study focuses on improving the measure of the amount of 'qualitative' academic research performed in host countries, i.e. the number of ISI listed journal publications originating in these countries. While the ISI database only includes reputable peer-reviewed journals, there is heterogeneity in quality among listed journals. One way to take into account these quality differences is to weight countries' publication totals by journal impact factors. Second, an interesting question is what type of academic research (basic or applied) is valued most by multinational firms in their R&D location choices. One way to distinguish between basic and applied academic research is to use the CHI classification scheme for ISI listed journals, which classifies journals into one of four research levels, in a spectrum ranging from very basic to applied, target research (Lim et al, 2004). Third, future work may use information on citations in patent documents to make a rough distinction between more 'innovative' R&D (patents receiving more citations) and more development oriented R&D (incremental innovations), and examine differences in internationalization drivers between the type types of (foreign) R&D. Finally, an important question remains under what circumstances and to what extent a broader geographic and international distribution of R&D improves the productivity of multinational firms' global R&D activities, and hence their economic performance (Griffith et al, 2008).

REFERENCES

Abramovsky, L., Harrison, R. Simpson, H. 2007 University Research and the Location of Business R&D. *Economic Journal*, 117(519), pp. C114-41

Acs Z., Audretsch D. and Feldman M. (1994). R&D spillovers and recipient firm size. *The Review of Economics and Statistics*, 76, 336-340.

Acs Z., Audretsch D. and Feldman M. (1991). Real effects of academic research: Comment. *American Economic Review*, 81, 363-367.

Ai C.R. and Norton E.C. (2003). Interaction Terms in logit and probit models. *Economics Letters*, 80 (1), 123-129

Alcacer J. and Chung W. (2007). Location strategies and knowledge spillovers. *Management Science*, 53(5), 760-776.

Allred B. and Park W. (2007). Patent rights and innovative activity: Evidence from national and firm-level data. *Journal of International Business Studies*, 38, 878-900.

Ambos B. (2005). Foreign direct investment in industrial research and development: a study of German MNCs. *Research Policy*, 34(4), 395-410.

Anselin L., Varga A. and Acs Z. (1997). Local geographic spillovers between university research and high technology innovations. *Journal of Urban Economics*, 42, 422-448

Bania N., Calkins L. and Dalenberg, R. (1992). The effects of regional science and technology policy on the geographic distribution of industrial R&D laboratories. *Journal of Regional Science*, 32, 209-228.

Basberg B. (1987). Patents and the measurement of technological change: A survey of the literature. *Research Policy*, 16, 131-141.

Belderbos R. (2001). Overseas Innovations by Japanese Firms: An Analysis of Patent and Subsidiary Data. *Research Policy*, 30, 2, 313-332.

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., Carree M. and Lokshin B. (2004). R&D cooperation and firm performance. *Research Policy*, 33(10), 1477-1492.

Belderbos R., Lykogianni E. and Veugelers R. (2008). Strategic R&D location in European Manufacturing Industries. *Journal of World Economics*, 14 (2).

Belderbos R., Fukao K. and Iwasa T. (2009). Domestic and foreign R&D investment. *Economics of Innovation and New Technologies* 18 (4), 369–380,

Berry H. (2006). Leaders, laggards, and the pursuit of foreign knowledge. *Strategic Management Journal*, 27, 151-168.

Booz Allen Hamilton and INSEAD (2006). Innovation: Global the Way Forward?, *INSEAD*, Fontainebleau France and Booz Allen Hamilton

Branstetter L. and Kwon H. (2004). The restructuring of Japanese research and development: The increasing impact of science on Japanese R&D. *RIETI Discussion Paper Series* 04-E-021.

Branstetter L., Fisman R. and 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.

Callaert J., Van Looy B., Verbeek A., Debackere K. and Thijs, B. (2006). Traces of prior art: An analysis of non-patent references found in patent documents. *Scientometrics*, 69(1) 3-20.

Cantwell J. and 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. and 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. and Alcacer J. (2002). Knowledge Seeking and Location Choice of Foreign Direct Investment in the United States. *Management Science*, 48(12): 1534- 1554.

Clogg C., Petkova E. and Adamantios H. (1995). Statistical Methods for Comparing Regression Coefficients between Models. *American Journal of Sociology* 100:1261-93.

Cockburn I. and Henderson R. (1998). Absorptive Capacity, Co-authoring behaviour, and the Organization of Research in Drug Discovery. *Journal of Industrial Economics*, 46(2), 157-182.

Cockburn I., Henderson R. and Stern S. (1999). The Diffusion of Science-Driven Drug Discovery: Organizational Change in Pharmaceutical Research. *NBER Working Paper* no. 7359, National Bureau of Economic Research Inc.

Cohen, W. and Levinthal D. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, Vol. 35, 128-152.

Cohen W., Nelson R. and Walsh J. (2002). Links and impacts: The influence of public research on industrial R&D. *Management Science*, 48(1), 1-23.

Deyle H. And Grupp H. (2005). Commuters and the regional assignment of innovative activities: A methodological patent study of German districts. *Research Policy*, 34, 221-234.

Edler J., Meyer-Krahmer F. and Reger G. (2002). Changes in the strategic management of technology: results of a global benchmark survey. *R&D Management*, 32(2), 149-164.

Fabrizio K. (2009). Absorptive capacity and the search for innovation. *Research Policy* (forthcoming).

Fleming L. and 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.

Fors G. (1997). Utilization of R&D Results in the Home and Foreign Plants of Multinationals. *Journal of Industrial Economics*, 45, 3, 341-358.

Frost T. (2001). The geographic sources of foreign subsidiaries' innovation. *Strategic Management Journal*, 22, 101-124.

Frost and Sullivan (2004). Outsourcing Technology in Asia: Analysis of the Changing Face of R&D (San Antonio, TX: Frost and Sullivan Company).

Furman, J., Kyle, M., Cockburn, I. and Henderson, R. (2006). Public & Private Spillovers, Location and the Productivity of Pharmaceutical Research. *NBER Working Papers*: 12509. Forthcoming in *Annales d'Economie et de Statistique*.

Furman, J. (2003). Location and Organizing Strategy: Exploring the Influence of Location on the Organization of Pharmaceutical Research. *Geography and strategy*, pp. 49-87

Furman, J. and MacGarvie, M. (2007). Academic Science and the Birth of Industrial Research Laboratories in the U.S. Pharmaceutical Industry, *Journal of Economic Behavior and Organization*, 63(4), pp. 756-76

Gambardella A. (1992). Competitive advantages from in-house scientific research: The US pharmaceutical industry in the 1980s. *Research Policy*, 21, 391-407.

Griffith R., Harrison R. and Van Reenen J. (2008). How special is the special relationship? Using the impact of US R&D spillovers on UK firms as a test of technology sourcing. *American Economic Review*, 96(5), 1859-1875.

Griliches Z. (1990). Patent statistics as economic indicators - a survey. *Journal of Economic Literature*, 28(4), 1661-1707.

Guellec D. and Van Pottelsberghe B. (2001). The internationalisation of technology analysed with patent data. *Research Policy*, 30 (8), 1256-1266.

Gupta A. K. and Govindarajan V. (2000). Knowledge Flows within Multinational Corporations, *Strategic Management Journal*, 21, 473-496.

Hakanson L. and Nobel R. (1993). Foreign research and development in Swedish multinationals. *Research Policy*, 22, 373-396.

Hall, Bronwyn H., Albert N. Link & John T. Scott, 2003, Universities as Research Partners, *The Review of Economics and Statistics*, MIT Press, vol. 85(2), pages 485-491, 01.

Hegde D. and Hicks D. (2008). The maturation of global corporate R&D: Evidence from the activity of U.S. foreign subsidiaries. *Research Policy*, 390-406.

Hoetker G., (2007). The use of logit and probit models in strategic management research: Critical issues. *Strategic Management Journal*, 28, 331-343.

Hosmer D. and Lemeshow S. (2000). *Applied Logistic Regression*. Wiley, New York, second edition.

Iwasa T. and 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.

King G. and Zeng L. (2001). Logistic regression in rare events data. *Political Analysis*, 9(2), 137-163.

Kenny M. and Florida R. (1994). The organization and geography of Japanese R&D: results from a survey of Japanese electronics and biotechnology firms. *Research Policy*, 23, 305-323.

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.

Kuemmerle W. (1998). Optimal Scale for Research and Development in Foreign Environments: An Investigation into Size and Performance of Research and Development Laboratories Abroad. *Research Policy*, 27, 111-126.

Kuemmerle W. (1997). Building Effective R&D Capabilities Abroad. *Harvard Business Review*, March / April, 61-70.

Kumar, N. (2001). Determinants of location of overseas R&D activity of multinational enterprises: The case of US and Japanese corporations. *Research Policy*, 30, 1, pp. 159-174.

Le Bas C. and Sierra C. (2002). Location versus home country advantages in R&D activities: Some further results on multinationals location strategies. *Research Policy*, 31, 589-609.

Liebeskind J.P., Oliver A.L., Zucker L. and 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.

Mansfield E. (1995). Academic research underlying industrial innovations: Sources, characteristics and financing. *The Review of Economics and Statistics*, 77, 55- 65

Mowery D., Sampat B. and Ziedonis A. (2002). Learning to patent: Institutional experience, learning and the characteristics of U.S. university patents after the Bayh-Dole Act, 1981-1992. *Manegement Science*, 48(1), 73-89.

Nachum L., Zaheer S. and Gross S. (2008). Does it matter where countries are? Proximity to knowledge, markets and resources, and MNE location choices. *Management Science*, 54(7), 1252-1265.

Narin F. and Noma E. (1985). Is technology becoming science? *Scientometrics*, 7, 369-381.

Nobel R. and Birkinshaw J., 1998, Innovation in multinational corporations: control and communication patterns in international R&D operations, Strategic Management Journal, 19-5, 479-496

Odagiri H. and Yasuda H. (1996). The Determinants of Overseas R&D by Japanese Firms: An Empirical Study at the Industry and Company Levels. *Research Policy*, 25, 1059-1079.

OECD (2007). Intellectual Assets and International Investment: A stocktaking of the evidence. *Report to the OECD Investment Committee* DAF/INV/WD(2007)6, Paris, OECD.

Patel P. and Pavitt K. (1991). Large firms in the production of the world's technology: An important case of 'non-globalization'. *Journal of International Business Studies*, 22(1), 1-21.

Patel P. and Vega M. (1999). Patterns of internationalisation of corporate technology: Location vs. home country advantages. *Research Policy*, 28, 145-155.

Park W. and Wagh S. (2002). Index of patent rights. *Economic freedom of the world: 2002 annual report*, chapter 2, 33-43.

Penner-Hahn J. and Shaver M. (2005). Does international research and development increase patent output? An analysis of Japanese pharmaceutical firms. *Strategic Management Journal*, 26, 121-140.

Rosenberg N. (1990). Why do firms do basic research (with their own money)? *Research Policy*, 19(2), 165-174.

Shaver J. and Flyer F. (2000). Agglomeration economies, firm heterogeneity, and foreign direct investment in the United States. *Strategic Management Journal*, 21(12), 1175-1193.

Shimizutani, S. and Todo, Y. (2007). What determines overseas R&D activities? The case of Japanese multinational firms. *Research Policy*, 37, 530–544

Singh, J. (2007). Asymmetry of knowledge spillovers between MNCs and host country firms. *Journal of International Business Studies*, 38(5), 764-786.

Singh, J. (2008). Distributed R&D, cross-regional knowledge integration and quality of innovative output. *Research Policy*, 37, 77-96

Song, J. and Shin, J. (2008). The paradox of technological capabilities: a study of knowledge sourcing from host countries of overseas R&D operations. *Journal of International Business Studies*, 39, 291–303.

Thursby J. and 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.

Tijssen R. (2001). Global and domestic utilization of industrial relevant science: patent citation analysis of science-technology interactions and knowledge flows. *Research Policy*, 30, 35-54.

Todo Y. and Shimizutani S. (2008). Overseas R&D Activities and home productivity growth. *Journal of Industrial Economics*, 56(4), 752-777.

UNCTAD (2005). World Investment Report 2005, New York: United Nations.

Van Vianen B., Moed H. and Van Raan A. (1990). An exploration of the science base of recent technology. *Research Policy*, 19, 61-81.

Veugelers, R. and Cassiman B. (2004). Foreign subsidiaries as channel of international technology diffusion: Some direct firm level evidence from Belgium. *European Economic Review*, 48, 455-476.

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.

Wooldridge J. (2002). *Econometric analysis of cross-section and panel data*. MIT Press, Cambridge (Massachusetts).

Zhao M. (2006). Conducting R&D in countries with weak intellectual property rights protection. *Management Science*, 52(8), 1185-1199.

Zejan M.C. (1990). R&D activities in affiliates of Swedish multinational enterprises. *Scandinavian Journal of Economics*, 92, 487-500.

Zucker L., Darby M., and Brewer M. (1998). Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises. *American Economic Review*, 88 (1), 290-306.

Zucker L. and 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. and Armstrong J. (2002). Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology. *Management Science*, 48(1), 2002.

Table 1: Foreign R&D - Firms' Patents by Country of Invention, 1995-2002

	European Firms	US firms	Japanese firms
Firm's home country	49573	32776	56461
%	*61,2%*	*76,1%*	*92,3%*
Europe	19124	7711	2358
%	*23,6%*	*17,9%*	*3,9%*
Austria	1032	42	21
Belgium	1522	338	68
Denmark	403	136	12
Finland	615	20	0
France	1691	1361	207
Germany	5911	1699	1054
Greece	18	5	0
Hungary	86	7	3
Ireland	60	102	24
Italy	2397	306	29
Luxembourg	4	2	9
Netherlands	772	395	70
Norway	268	24	4
Poland	39	5	0
Portugal	11	1	0
Spain	297	267	4
Sweden	1403	112	68
Switzerland	948	315	22
United Kingdom	1647	2574	763
USA	9949		2085
%	*12,3%*		*3,4%*
Japan	703	1030	
%	*0,9%*	*2,4%*	
Rest of Asia	642	786	141
%	*0,8%*	*1,8%*	*0,2%*
China	131	35	15
Hong Kong	25	8	0
India	65	68	6
Indonesia	10	0	3
Israel	50	405	6
Malaysia	23	10	7
Philippinnes	2	7	0
Republic of Korea	57	34	30
Russia	59	20	3
Singapore	195	127	63
Taiwan	20	68	4
Thailand	5	4	4
South America	64	59	2
%	*0,1%*	*0,1%*	*0,0%*
Argentina	4	2	1
Brazil	58	55	1
Colombia	2	2	0
Rest of World	932	700	117
%	*1,2%*	*1,6%*	*0,2%*
Australia	187	125	76
Canada	686	551	39
Mexico	23	18	2
South-Africa	36	6	0
Total	80987	43062	61164

Table 2: Host Countries' Academic Research Output: Publications by Technology Class

	Electrical Eng.		Instruments		Chem/Pharma		Process Eng.		Mechanic Eng.		Ex Sc.
Europe	364.245	*9%*	438.804	*11%*	2.495.952	*61%*	785.385	*19%*	477.865	*12%*	4.088.560
Austria	6.997	*8%*	9.057	*11%*	53.828	*65%*	14.590	*18%*	7.895	*10%*	82.981
Belgium	11.152	*9%*	13.497	*11%*	77.469	*64%*	21.210	*18%*	10.926	*9%*	120.297
Denmark	6.135	*7%*	7.675	*9%*	59.008	*66%*	15.337	*17%*	9.799	*11%*	90.087
Finland	6.990	*8%*	7.530	*9%*	55.230	*65%*	14.926	*18%*	7.870	*9%*	84.722
France	55.379	*10%*	64.937	*11%*	328.816	*58%*	122.014	*21%*	75.805	*13%*	571.599
Germany	72.280	*9%*	99.564	*13%*	450.707	*59%*	164.150	*21%*	93.100	*12%*	764.573
Greece	7.951	*14%*	6.356	*11%*	29.219	*51%*	11.957	*21%*	8.469	*15%*	56.963
Hungary	4.304	*9%*	5.983	*13%*	27.176	*58%*	9.829	*21%*	4.253	*9%*	46.619
Ireland	2.498	*8%*	2.202	*7%*	19.406	*65%*	5.156	*17%*	2.975	*10%*	29.730
Italy	41.362	*11%*	51.717	*14%*	230.766	*60%*	65.497	*17%*	47.099	*12%*	382.816
Luxembourg	42	*4%*	57	*5%*	809	*77%*	112	*11%*	64	*6%*	1.049
Netherlands	17.233	*8%*	18.727	*8%*	151.444	*66%*	36.885	*16%*	23.677	*10%*	229.027
Norway	3.124	*5%*	3.650	*6%*	35.158	*60%*	10.883	*19%*	8.342	*14%*	58.473
Poland	13.277	*12%*	17.755	*16%*	50.151	*46%*	36.028	*33%*	15.668	*14%*	108.996
Portugal	3.603	*10%*	4.204	*12%*	16.903	*48%*	9.876	*28%*	4.415	*13%*	34.852
Spain	20.265	*8%*	21.984	*9%*	162.390	*63%*	53.761	*21%*	23.895	*9%*	257.532
Sweden	12.607	*7%*	15.346	*9%*	117.720	*66%*	32.061	*18%*	17.332	*10%*	178.445
Switzerland	14.956	*9%*	24.568	*15%*	99.716	*62%*	28.085	*17%*	17.927	*11%*	161.102
United Kingdom	64.090	*8%*	63.995	*8%*	530.036	*64%*	133.028	*16%*	98.354	*12%*	828.697
USA	265.442	*9%*	238.367	*8%*	1.953.637	*64%*	434.239	*14%*	352.973	*12%*	3.038.709
Japan	110.139	*12%*	104.762	*11%*	510.902	*54%*	204.875	*22%*	101.236	*11%*	949.969
Rest of Asia	195.197	*16%*	199.715	*16%*	523.392	*42%*	367.983	*30%*	227.313	*18%*	1.246.204
China	40.794	*15%*	44.368	*16%*	103.714	*37%*	93.848	*34%*	52.204	*19%*	278.655
Hong Kong	5.070	*20%*	2.680	*10%*	11.667	*46%*	5.253	*21%*	3.766	*15%*	25.564
India	21.583	*11%*	22.017	*11%*	103.212	*51%*	53.966	*27%*	29.183	*14%*	201.290
Indonesia	161	*3%*	240	*5%*	3.104	*62%*	963	*19%*	736	*15%*	4.980
Israel	12.900	*12%*	12.150	*11%*	64.941	*59%*	19.502	*18%*	12.814	*12%*	109.794
Malaysia	598	*11%*	577	*11%*	6.049	*51%*	2.757	*27%*	805	*14%*	10.029
Philippines	116	*3%*	140	*3%*	2.972	*70%*	895	*21%*	272	*6%*	4.254
Korea	28.782	*20%*	21.146	*15%*	61.539	*44%*	43.474	*31%*	24.831	*18%*	141.129
Russia	50.510	*17%*	77.445	*26%*	93.581	*31%*	106.404	*35%*	73.450	*24%*	300.083
Singapore	10.039	*25%*	4.892	*12%*	12.625	*32%*	10.448	*26%*	7.728	*20%*	39.503
Taiwan	23.875	*20%*	13.622	*12%*	49.480	*42%*	28.259	*24%*	20.531	*18%*	116.533
Thailand	769	*5%*	438	*3%*	10.508	*73%*	2.214	*15%*	993	*7%*	14.390
South America	15.204	*9%*	19.550	*12%*	99.871	*60%*	39.343	*23%*	20.868	*12%*	167.718
Argentina	3.521	*7%*	4.728	*10%*	28.942	*61%*	11.264	*24%*	6.002	*13%*	47.591
Brazil	11.189	*10%*	14.129	*12%*	66.993	*59%*	26.557	*23%*	14.106	*12%*	113.751
Colombia	494	*8%*	693	*11%*	3.936	*62%*	1.522	*24%*	760	*12%*	6.376
Rest of World	55.817	*7%*	51.144	*7%*	461.525	*60%*	125.651	*16%*	94.317	*12%*	767.090
Australia	17.615	*7%*	15.055	*6%*	154.325	*62%*	40.030	*16%*	30.165	*12%*	247.052
Canada	30.813	*7%*	26.327	*6%*	254.589	*60%*	63.407	*15%*	49.849	*12%*	424.985
Mexico	5.463	*11%*	7.235	*14%*	26.814	*52%*	13.958	*27%*	8.558	*17%*	51.532
South-Africa	1.926	*4%*	2.527	*6%*	25.797	*59%*	8.256	*19%*	5.745	*13%*	43.521
Total	999.766	*10%*	1.044.864	*10%*	5.985.630	*59%*	1.939.876	*19%*	1.263.295	*12%*	10.163.729

Table 3: Descriptive Statistics and Definitions of Variables

Name	Description	Mean	Stdev
Foreign R&D (Dep. Var.)	Binary variable denoting if firm *i* has applied for a patent in a technology field *j*, where the inventive activity took place in host country *c*.	0.05	0.21
Academic Research	Logarithm of the number of ISI publications of a host country in a technology main class (expressed in hundreds)	2.92	1.69
Technological Strength	Logarithm of the number of patents of a host country in a technology class (excluding those belonging to the firm)	2.54	1.94
Technological Strength Related Fields	Logarithm of the number of patents of a host country in technology classes belonging to main technology class, excluding own technology class and patents belonging to the firm)	3.84	2.08
IPR Protection	Logarithm of the IPR index (0-10) from the Global Competitiveness Report for the years 1995 and 2000	1.77	0.36
GDP per Capita	Logarithm of GDP per Capita in host country (thousand US$)	2.58	0.68
Market Size	Logarithm of (production + imports - exports) in a host country and sector (thousand US$)	1.82	1.49
Engineering Wage	Logarithm of yearly gross income of engineers from a host country in 1994 and 1997 (thousand US$)	3.40	0.92
European Host Country	Dummy taking the value 1 if a host country is an European country	0.50	0.50
Language Similarity	Dummy taking the value 1 if home and host countries share at least one official language	0.09	0.29
Geographic Distance	Logarithm of geographic distance between the capital cities of home and host countries (hundred Km)	4.04	0.93
Firm's Science Orientation	Logarithm of one plus the average number of scientific non-patent references listed on the firm's prior 3 year patent portfolio	0.16	0.16
Firm's Technological. Strength	Logarithm of the number of the firm's patents in the technology field	1.16	1.27
Firm's Total Patents	Logarithm of the total number of the firm's patents	4.15	1.42
International R&D Experience	Logarithm of the number of years since the firm reported its first foreign based invention in a patent application	2.51	0.58
Firm Age	Logarithm of the number of years since the firm was founded	4.29	0.62
Manufacturing/Sales Subsidiary	Dummy taking the value 1 if a firm operated a manufacturing or sales subsidiary in the host country.	0.47	0.50

Note: All explanatory variables are one year lagged, except when mentioned differently.

Table 4: Logit Model Estimates of the Propensity to Conduct Foreign R&D by Country and Technology field, 1995-1998 and 1999-2002

	1995 - 1998		1999 - 2002	
	Model 1	Model 2	Model 1	Model 2
Host Country Variables				
Academic Research	0.2382***	0.1887**	0.2155***	0.1328*
	(0.0783)	(0.0851)	(0.0774)	(0.0803)
Academic Research * Firm's Science Orientation		0.3160**		0.5350***
		(0.1557)		(0.1984)
Technological Strength	0.4008***	0.4010***	0.4264***	0.4231***
	(0.0417)	(0.0419)	(0.0379)	(0.0375)
Technological Strength in Related Fields	0.1073*	0.1053*	0.1184**	0.1143**
	(0.0622)	(0.0622)	(0.0517)	(0.0516)
IPR Protection	0.8911***	0.8895***	1.1968***	1.1906***
	(0.2365)	(0.2371)	(0.2758)	(0.2784)
GDP per Capita	0.3558**	0.3509**	0.0337	0.0438
	(0.1742)	(0.1729)	(0.1732)	(0.1743)
Market Size	0.1328***	0.1285***	0.1071*	0.1353**
	(0.0459)	(0.0474)	(0.0547)	(0.0548)
Engineering Wage	-0.3530**	-0.3480**	-0.4490***	-0.4542***
	(0.1552)	(0.1545)	(0.1322)	(0.1323)
European Host Country	0.0553	0.0524	-0.0914	-0.0852
	(0.1056)	(0.1070)	(0.1025)	(0.1028)
Language Similarity	0.5441***	0.5428***	0.6398***	0.6391***
	(0.1221)	(0.1213)	(0.1020)	(0.1019)
Geographic Distance	-0.1569***	-0.1533***	-0.2178***	-0.2180***
	(0.0589)	(0.0587)	(0.0505)	(0.0505)
Firm Variables				
Firm's Science Orientation		-1.5164*		-1.6709
		(0.8070)		(1.1109)
Firm's Technological Strength	0.8298***	0.8298***	0.8142***	0.8131***
	(0.0260)	(0.0257)	(0.0239)	(0.0236)
Firm's Total Patents	-0.0144	-0.0071	0.0114	0.0110
	(0.0415)	(0.0440)	(0.0444)	(0.0453)
International R&D Experience	0.3001**	0.3034**	0.1858	0.1658
	(0.1433)	(0.1433)	(0.1382)	(0.1338)
Firm's Age	-0.1494	-0.1547	-0.0634	-0.0524
	(0.1022)	(0.1062)	(0.1062)	(0.1074)
Manufacturing or Sales Subsidiary	0.7054***	0.7060***	0.5723***	0.5771***
	(0.1056)	(0.1054)	(0.0945)	(0.0948)

Table 4 (Continued)

	1995 - 1998		1999 - 2002	
	Model 1	Model 2	Model 1	Model 2
Home Country Dummies				
Japan	-1.2975***	-1.2980***	-1.4035***	-1.4539***
	(0.1354)	(0.1366)	(0.1663)	(0.1705)
Belgium	0.1380	0.1564	0.2396	0.2821
	(0.2525)	(0.2551)	(0.1759)	(0.1900)
Switzerland	0.4237	0.4011	0.5545***	0.6157***
	(0.3745)	(0.3628)	(0.2083)	(0.2067)
Germany	0.2233	0.2198	0.2487	0.2783
	(0.1526)	(0.1543)	(0.2014)	(0.2020)
Denmark	0.3281	0.3236	0.3037	0.3462
	(0.7780)	(0.7753)	(0.3602)	(0.3640)
Finland	0.3828*	0.3823*	0.6124**	0.6790**
	(0.2322)	(0.2208)	(0.2663)	(0.2693)
France	-0.1004	-0.0835	0.0346	0.0429
	(0.1551)	(0.1548)	(0.1635)	(0.1638)
Great Britain	0.1273	0.1361	0.0918	0.1432
	(0.2918)	(0.2894)	(0.1445)	(0.1468)
Netherlands	0.1840	0.2065	-0.3852	-0.3284
	(0.2016)	(0.1994)	(0.3992)	(0.4103)
Sweden	0.5635***	0.5422***	0.1972	0.2445
	(0.1766)	(0.1746)	(0.1565)	(0.1669)
Technology Dummies (29)	Included	Included	Included	Included
Constant	-8.6726***	-8.4455***	-8.5579***	-8.3230***
	(0.6273)	(0.6625)	(0.6759)	(0.6925)
Number of Observations	87089	87089	100326	100326
Log Likelihood	-9321	-9314	-11990	-11965
McFadden Pseudo R2	0.3851	0.3855	0.3990	0.4003
Correct Prediction for 1 (%) - Sensitivity	86,01	86,04	85,58	85,46
Correct Prediction for 0 (%) - Specificity	83,26	83,24	83,43	83,46
ROC	0,9211	0,9212	0,9225	0,9228
Interaction Effect				
% of positive values (significant)		90.0 (18.4)		98.5 (84.9)
% of negative values (significant)		10.0 (0.4)		1.5 (0.1)
LR Tests				
Chi-2 Model 2 versus Model 1		12.50***		48.82***

Notes: Robust standard errors, clustered by parent firm, in parentheses; ***,**,* indicate significant at the 1, 5 and 10 percent levels.
Mc Fadden Pseudo R2 is calculated as 1-(log likelihood model with only intercept / log likelihood full model).
US is the reference group for the Home Country Dummies. Significant cross-derivative is evaluated at the 10% level. The mean sample probability (4,19% for period 1; 5,01% for period 2) is taken as benchmark to evaluate the number of correct predictions.

Table 5: Logit Model Estimates of the Propensity to Conduct Foreign R&D by Country and Technology field, 1995-1998 and 1999-2002; Split Sample Analysis by Firms' Science Orientation

	1995 - 1998		1999 - 2002	
	Science Orientation		Science Orientation	
	Low	High	Low	High
Host Country Variables				
Academic Research	0.0585	0.4402***	0.0755	0.4128***
	(0.1039)	(0.0923)	(0.0864)	(0.1095)
Technological Strength	0.3526***	0.4196***	0.4956***	0.3247***
	(0.0705)	(0.0523)	(0.0494)	(0.0555)
Technological Strength in Related Fields	0.2394**	-0.0310	0.1701**	0.0464
	(0.1035)	(0.0682)	(0.0697)	(0.0728)
IPR Protection	0.4272	1.2096***	1.0100**	1.3635***
	(0.4109)	(0.2956)	(0.4003)	(0.3556)
GDP per Capita	0.3993	0.3109	-0.1277	0.2089
	(0.2746)	(0.2054)	(0.2505)	(0.1862)
Market Size	0.1265	0.1614***	0.0613	0.2024***
	(0.0788)	(0.0540)	(0.0783)	(0.0676)
Engineering Wage	-0.2895	-0.3031*	-0.4530**	-0.4129**
	(0.2518)	(0.1703)	(0.1842)	(0.1618)
European Host Country	0.3282**	-0.0964	0.1296	-0.1786
	(0.1545)	(0.1421)	(0.1477)	(0.1407)
Language Similarity	0.7683***	0.3378**	0.6767***	0.6378***
	(0.1876)	(0.1655)	(0.1431)	(0.1391)
Geographic Distance	-0.0755	-0.1949**	-0.1278**	-0.2517***
	(0.0744)	(0.0949)	(0.0644)	(0.0858)
Firm Variables				
Firm's Technological Strength	0.8101***	0.8474***	0.8164***	0.8226***
	(0.0406)	(0.0395)	(0.0326)	(0.0371)
Firm's Total Patents	0.1012*	-0.1499**	0.0737	-0.0058
	(0.0597)	(0.0663)	(0.0595)	(0.0815)
International R&D Experience	0.2755	0.3330	0.1433	0.2897
	(0.2004)	(0.2105)	(0.1653)	(0.2463)
Firm's Age	-0.4100**	0.0414	-0.2609*	0.0440
	(0.1609)	(0.1303)	(0.1501)	(0.1278)
Manufacturing or Sales Subsidiary	0.9871***	0.5377***	0.6236***	0.5700***
	(0.1623)	(0.1383)	(0.1348)	(0.1374)

Table 5 (Continued)

	1995 - 1998		1999 - 2002	
	Science Orientation		Science Orientation	
	Low	High	Low	High
Home Country Dummies				
Japan	-1.3718***	-1.3682***	-1.3499***	-1.5212***
	(0.2414)	(0.1670)	(0.3747)	(0.2015)
Belgium	-0.3631*	0.0512	0.6268***	-0.0846
	(0.2011)	(0.3368)	(0.2151)	(0.2405)
Switzerland	0.5355*		0.7610***	
	(0.3193)		(0.2585)	
Germany	0.2400	0.2960	0.2856	0.6715**
	(0.1839)	(0.2118)	(0.2971)	(0.2738)
Denmark	0.5644	-0.9769***	0.4948	0.1596
	(0.8012)	(0.2974)	(0.3412)	(0.3110)
Finland	0.5329***		0.6509***	
	(0.1779)		(0.2022)	
France	-0.0980	-0.1255	0.1727	-0.1015
	(0.2325)	(0.2225)	(0.2555)	(0.2104)
Great Britain	0.2809	-0.4040	0.1541	0.1444
	(0.3374)	(0.5213)	(0.1929)	(0.4170)
Netherlands	0.7310*	0.1547	-0.4771	1.0131***
	(0.4316)	(0.2048)	(0.3956)	(0.2391)
Sweden	0.8411***		0.3372	
	(0.1955)		(0.2160)	
Technology Dummies (29)	Included	Included	Included	Included
Constant	-7.9811***	-9.3219***	-7.5401***	-10.0376***
	(0.9326)	(0.8408)	(0.9908)	(0.8551)
Number of Observations	40450	46537	48096	52192
Log Likelihood	-4467	-4740	-6656	-5219
McFadden Pseudo R2	0.3648	0.4162	0.3880	0.4191
Correct Prediction for 1 (%) - Sensitivity	85,36	87,23	84,54	86,46
Correct Prediction for 0 (%) - Specificity	82,05	84,53	82,51	84,88
ROC	0,9162	0,9293	0,9161	0,9311

Notes: Robust standard errors, clustered by parent firm, in parentheses; ***,**,* indicate significant at the 1, 5 and 10 percent levels.
US is the reference group for the Home Country Dummies;

Table 6: Negative Binomial Model Estimates of the Propensity to Conduct Foreign R&D by Country and Technology field, 1995-1998 and 1999-2002

	1995 - 1998	1999 - 2002
Host Country Variables		
Academic Research	0.2482***	-0.0126
	(0.0911)	(0.0833)
Academic Research * Firm's Science Orientation	0.1590	0.6585***
	(0.1732)	(0.1929)
Technological Strength	0.3756***	0.4452***
	(0.0602)	(0.0517)
Technological Strength in Related Fields	0.1639**	0.2782***
	(0.0833)	(0.0675)
IPR Protection	0.9223***	1.0045***
	(0.3113)	(0.3449)
GDP per Capita	0.5905***	-0.0177
	(0.1949)	(0.1879)
Market Size	0.0803	0.0907
	(0.0729)	(0.0590)
Engineering Wage	-0.3284*	-0.3428**
	(0.1812)	(0.1557)
European Host Country	0.1256	0.0473
	(0.1546)	(0.1412)
Language Similarity	0.3610**	0.6363***
	(0.1564)	(0.1308)
Geographic Distance	-0.3026***	-0.1666**
	(0.0825)	(0.0663)
Firm Variables		
Firm's Science Orientation	-1.1679	-2.5779*
	(0.9495)	(1.3797)
Firm's Technological Strength	1.0059***	1.0081***
	(0.0368)	(0.0280)
Firm's Total Patents	-0.0141	-0.0174
	(0.0618)	(0.0611)
International R&D Experience	-0.0263	0.1028
	(0.1800)	(0.1892)
Firm's Age	-0.1050	-0.2133
	(0.1215)	(0.1407)
Manufacturing or Sales Subsidiary	0.9796***	0.8449***
	(0.1337)	(0.1219)

Table 6 (Continued)

	1995 - 1998	1999 - 2002
Home Country Dummies		
Japan	-1.5079***	-1.5784***
	(0.1685)	(0.2082)
Belgium	-0.1650	0.4958**
	(0.2640)	(0.2165)
Switzerland	0.5592	0.8438***
	(0.4179)	(0.2438)
Germany	0.1607	0.3675
	(0.2305)	(0.2320)
Denmark	1.0323	0.9654*
	(0.7519)	(0.5172)
Finland	0.1161	0.6229***
	(0.2544)	(0.2391)
France	-0.1009	0.3259
	(0.2850)	(0.2388)
Great Britain	0.0931	0.2806
	(0.2555)	(0.2692)
Netherlands	-0.1374	-0.1118
	(0.2172)	(0.3414)
Sweden	0.6929**	0.3009
	(0.2968)	(0.2296)
Technology Dummies (29)	Included	Included
Constant	-8.1242***	-7.5929***
	(0.7383)	(0.7512)
ln alpha	1.9686***	1.8580***
	(0.0829)	(0.0756)
Number of Observations	87089	100326
Log Likelihood	-17507	-23896
Wald Chi2	7478	10326
McFadden's Adj. R2	0.254	0.258
Interaction Effect		
% of positive values (significant)	27.9 (0)	99.4 (82.6)
% of negative values (significant)	72.1 (0,1)	0.6 (0.1)

Notes: Robust standard errors, clustered by parent firm, in parentheses; ***,**,* indicate significant at the 1, 5 and 10 percent levels. US is the reference group for the Home Country Dummies.

Table 7: Logit Model Estimates of the Propensity to Conduct Foreign R&D by Country and Technology field, 1995-1998 and 1999-2002; Analysis with Lagged Dependent Variable

	1995 - 1998	1999 - 2002
Host Country Variables		
Prior R&D Activities	2.4448***	2.3832***
	(0.1361)	(0.0995)
Academic Research	0.1722**	0.1134
	(0.0836)	(0.0771)
Academic Research * Firm's Science Orientation	0.2053	0.4287**
	(0.1432)	(0.1998)
Technological Strength	0.3638***	0.3804***
	(0.0430)	(0.0380)
Technological Strength in Related Fields	0.0997	0.1145**
	(0.0612)	(0.0546)
IPR Protection	0.7812***	0.9728***
	(0.2257)	(0.2673)
GDP per Capita	0.2997*	0.0110
	(0.1590)	(0.1638)
Market Size	0.1177***	0.1216**
	(0.0455)	(0.0531)
Engineering Wage	-0.2964**	-0.3865***
	(0.1431)	(0.1248)
European Host Country	0.0685	-0.0841
	(0.1069)	(0.0985)
Language Similarity	0.4877***	0.6106***
	(0.1121)	(0.0991)
Geographic Distance	-0.1112**	-0.2052***
	(0.0529)	(0.0461)
Firm Variables		
Firm's Science Orientation	-1.0100	-1.1039
	(0.7218)	(1.0958)
Firm's Technological Strength	0.7204***	0.6945***
	(0.0293)	(0.0243)
Firm's Total Patents	0.0004	0.0209
	(0.0431)	(0.0442)
International R&D Experience	0.2721*	0.0877
	(0.1453)	(0.1282)
Firm's Age	-0.1784*	-0.0312
	(0.1080)	(0.1108)
Manufacturing or Sales Subsidiary	0.6943***	0.5217***
	(0.1017)	(0.0884)

Table 7 (Continued)

	1995 - 1998	1999 - 2002
Home Country Dummies		
Japan	-1.1971***	-1.3640***
	(0.1307)	(0.1646)
Belgium	0.1597	0.1659
	(0.2997)	(0.1733)
Switzerland	0.4170	0.5885***
	(0.3530)	(0.1804)
Germany	0.2924**	0.3088
	(0.1490)	(0.1972)
Denmark	0.3219	0.3546
	(0.7442)	(0.3118)
Finland	0.4316*	0.7141**
	(0.2300)	(0.2931)
France	-0.1478	0.0116
	(0.1604)	(0.1636)
Great Britain	0.1788	0.1015
	(0.3120)	(0.1454)
Netherlands	0.2787	-0.3099
	(0.1983)	(0.3785)
Sweden	0.6325***	0.1720
	(0.1668)	(0.1625)
Technology Dummies (29)	Included	Included
Constant	-8.0006***	-7.6277***
	(0.6494)	(0.6737)
Number of Observations	87089	100326
Log Likelihood	-8811	-11254
McFadden Pseudo R2	0.4187	0.4359
Correct Prediction for 1 (%) - Sensitivity	86.09	84.90
Correct Prediction for 0 (%) - Specificity	84.18	84.65
ROC	0.9265	0.9288
Interaction Effect		
% of positive values (significant)	93.3 (0)	99.6 (85.3)
% of negative values (significant)	6.7 (0)	0.4 (0)

Notes: Robust standard errors, clustered by parent firm, in parentheses; ***,**,* indicate significant at the 1, 5 and 10 percent levels. US is the reference group for the Home Country Dummies.

Table 8: Logit Model Estimates of the Propensity to Conduct Foreign R&D by Country and Technology field, 1995-1998 and 1999-2002; Split Sample Analysis by Firms' Technological Leadership

	1995 - 1998		1999 - 2002	
	Laggards	Leaders	Laggards	Leaders
Host Country Variables				
Academic Research	0.2121	0.1580**	0.0441	0.1507**
	(0.1748)	(0.0777)	(0.1361)	(0.0723)
Academic Research * Firm's Science Orientation	0.1106	0.4116**	0.5704*	0.5271**
	(0.2624)	(0.1625)	(0.2989)	(0.2214)
Technological Strength	0.4420***	0.3922***	0.4162***	0.4232***
	(0.0984)	(0.0531)	(0.0864)	(0.0420)
Technological Strength in Related Fields	0.1287	0.0940	0.1425	0.1053**
	(0.1241)	(0.0629)	(0.1099)	(0.0510)
IPR Protection	0.9131*	0.9247***	0.7520*	1.2575***
	(0.5384)	(0.2476)	(0.4285)	(0.3002)
GDP per Capita	1.0039***	0.2323	0.9076**	-0.0878
	(0.3484)	(0.1690)	(0.4301)	(0.1601)
Market Size	0.0366	0.2000***	0.1129	0.1702***
	(0.0798)	(0.0488)	(0.0771)	(0.0574)
Engineering Wage	-0.7467**	-0.2681*	-0.7337***	-0.3865***
	(0.2970)	(0.1468)	(0.2476)	(0.1282)
European Host Country	0.1817	0.0194	0.2645*	-0.1875*
	(0.1793)	(0.1147)	(0.1440)	(0.1137)
Language Similarity	0.6780***	0.4595***	0.6596***	0.6221***
	(0.1567)	(0.1331)	(0.1429)	(0.1011)
Geographic Distance	-0.1277*	-0.1800***	-0.1264*	-0.2582***
	(0.0739)	(0.0645)	(0.0655)	(0.0538)
Firm Variables				
Firm's Science Orientation	-0.6869	-2.1014**	-1.6201	-2.0223*
	(1.2762)	(0.8547)	(1.9190)	(1.0529)
Firm's Technological Strength	0.6683***	0.8337***	0.6724***	0.7733***
	(0.1213)	(0.0350)	(0.0867)	(0.0396)
Firm's Total Patents	0.0081	0.0138	0.0129	0.0489
	(0.0538)	(0.0521)	(0.0487)	(0.0569)
International R&D Experience	0.1451	0.6226***	-0.0115	0.3628**
	(0.1161)	(0.1866)	(0.1518)	(0.1578)
Firm's Age	-0.0955	-0.2257*	-0.0657	-0.0642
	(0.1174)	(0.1214)	(0.1183)	(0.1089)
Manufacturing or Sales Subsidiary	0.5708***	0.7393***	0.6971***	0.5343***
	(0.1729)	(0.1072)	(0.1608)	(0.0967)

Table 8 (Continued)

	1995 - 1998		1999 - 2002	
	Laggards	Leaders	Laggards	Leaders
Home Country Dummies				
Japan	-1.2391***	-1.3139***	-1.3800***	-1.4788***
	(0.1902)	(0.1475)	(0.2037)	(0.1740)
Belgium	0.2432	-0.0436	0.5644*	0.0928
	(0.3684)	(0.1948)	(0.3026)	(0.2119)
Switzerland	0.3151	0.4312	0.7665***	0.5566**
	(0.4027)	(0.3493)	(0.2033)	(0.2466)
Germany	0.2137	0.1074	0.4816*	0.1291
	(0.2673)	(0.1581)	(0.2529)	(0.2238)
Denmark	0.9084*	-0.5979	0.4498	0.5136
	(0.4981)	(0.9438)	(0.3508)	(0.3575)
Finland	0.0329	0.6030**	0.5570**	0.6711**
	(0.2714)	(0.2360)	(0.2616)	(0.2698)
France	-0.2858	-0.0461	-0.0056	0.0208
	(0.2667)	(0.1448)	(0.2816)	(0.1733)
Great Britain	0.4574*	-0.2241	0.5641***	-0.1631
	(0.2484)	(0.2916)	(0.2026)	(0.1456)
Netherlands	0.3528	0.0480	0.2416	-0.7428*
	(0.3561)	(0.1676)	(0.2739)	(0.4013)
Sweden	0.4308	0.6177***	0.1622	0.2670
	(0.3996)	(0.1850)	(0.2499)	(0.1779)
Technology Dummies (29)	Included	Included	Included	Included
Constant	-8.8818***	-8.9600***	-8.7945***	-8.6859***
	(0.9951)	(0.7908)	(0.9583)	(0.7104)
Number of Observations	48774	38315	55554	44772
Log Likelihood	-3126	-6109	-3861	-8016
McFadden Pseudo R2	0.2793	0.3886	0.2844	0.3979
Correct Prediction for 1 (%) - Sensitivity	86.44	85.23	84.79	84.76
Correct Prediction for 0 (%) - Specificity	80.86	82.72	80.60	82.45
ROC	0.9004	0.9137	0.9002	0.9135
Interaction Effect				
% of positive values (significant)	74.7 (0)	88.9 (28,5)	99.6 (52.6)	96.5 (69.6)
% of negative values (significant)	25.3 (0)	11.1 (0,6)	0.4 (0)	3.5 (0.1)

Notes: Robust standard errors, clustered by parent firm, in parentheses; ***,**,* indicate significant at the 1, 5 and 10 percent levels.
US is the reference group for the Home Country Dummies.

Table 9: Logit Model Estimates of the Propensity to Conduct Foreign R&D by Country and Technology field, 1995-1998 and 1999-2002; Analysis at Aggregate Firm level

	1995 - 1998		1999 - 2002	
	Model 1	Model 2	Model 1	Model 2
Host Country Variables				
Academic Research	0.2466***	0.1796**	0.1969**	0.0967
	(0.0827)	(0.0874)	(0.0782)	(0.0806)
Academic Research * Firm's Science Orientation		0.3936**		0.8048***
		(0.1768)		(0.2596)
Technological Strength	0.3711***	0.3668***	0.4477***	0.4462***
	(0.0698)	(0.0703)	(0.0541)	(0.0538)
IPR Protection	0.5035*	0.5058*	0.8210**	0.8360**
	(0.2722)	(0.2736)	(0.3325)	(0.3348)
GDP per Capita	0.2098	0.2085	-0.2656*	-0.2720*
	(0.1592)	(0.1590)	(0.1513)	(0.1519)
Market Size	0.2312***	0.2363***	0.2046***	0.2053***
	(0.0590)	(0.0594)	(0.0639)	(0.0636)
Engineering Wage	-0.1659	-0.1615	-0.1316	-0.1305
	(0.1268)	(0.1267)	(0.1116)	(0.1125)
European Host Country	0.1544	0.1533	-0.0872	-0.0972
	(0.1310)	(0.1314)	(0.1247)	(0.1261)
Language Similarity	0.6667***	0.6624***	0.6346***	0.6307***
	(0.1320)	(0.1320)	(0.1292)	(0.1300)
Geographic Distance	-0.1558**	-0.1576***	-0.3265***	-0.3319***
	(0.0607)	(0.0606)	(0.0561)	(0.0562)
Firm Variables				
Firm's Science Orientation		-1.1472*		-2.0384**
		(0.6097)		(0.8617)
Firm's Total Patents	0.8557***	0.8762***	0.9646***	0.9833***
	(0.0785)	(0.0808)	(0.0732)	(0.0772)
International R&D Experience	0.2519*	0.2457*	0.0201	0.0136
	(0.1501)	(0.1487)	(0.1955)	(0.1940)
Firm's Age	0.0126	0.0155	-0.0532	-0.0565
	(0.1248)	(0.1300)	(0.1071)	(0.1085)
Manufacturing or Sales Subsidiary	0.8736***	0.8727***	0.7077***	0.7231***
	(0.1116)	(0.1130)	(0.0994)	(0.0993)

Table 9 (Continued)

	1995 - 1998		1999 - 2002	
	Model 1	Model 2	Model 1	Model 2
Home Country Dummies				
Japan	-1.2467***	-1.2375***	-1.5398***	-1.5809***
	(0.1720)	(0.1769)	(0.1773)	(0.1831)
Belgium	-0.3703	-0.3638	0.0124	0.0219
	(0.4558)	(0.4542)	(0.2832)	(0.2808)
Switzerland	0.1628	0.1148	0.2255	0.1704
	(0.3767)	(0.3496)	(0.2574)	(0.2493)
Germany	0.2981	0.2709	0.1008	0.0682
	(0.2479)	(0.2440)	(0.2962)	(0.2987)
Denmark	-0.2386	-0.2407	0.2491	0.2306
	(0.6719)	(0.6679)	(0.1556)	(0.1544)
Finland	0.1309	0.1242	0.1809	0.1417
	(0.5131)	(0.4894)	(0.5237)	(0.4917)
France	-0.3765	-0.3633	-0.4859*	-0.4857*
	(0.2679)	(0.2689)	(0.2661)	(0.2616)
Great Britain	0.2271	0.2118	-0.2131	-0.2365
	(0.3905)	(0.3881)	(0.2658)	(0.2679)
Netherlands	0.0754	0.0911	-0.2509	-0.3160
	(0.2348)	(0.2295)	(0.4421)	(0.4446)
Sweden	0.8179**	0.7645**	0.2731	0.1792
	(0.3887)	(0.3607)	(0.3430)	(0.3307)
Industry Dummies (4)	Included	Included	Included	Included
Constant	-6.4722***	-6.3252***	-0.4421	-0.1050
	(1.5873)	(1.5727)	(1.2912)	(1.3190)
Number of Observations	6486	6486	6722	6722
Log Likelihood	-1711	-1709	-1986	-1980
McFadden Pseudo R2	0.3957	0.3966	0.4006	0.4023
Correct Prediction for 1 (%) - Sensitivity	83.24	83.63	81.88	81.73
Correct Prediction for 0 (%) - Specificity	81.34	81.26	80.77	80.92
ROC	0.9005	0.9008	0.8976	0.8981
Interaction Effect				
% of positive values (significant)		89.1 (31.6)		96 (77.3)
% of negative values (significant)		10.9 (0.8)		4 (0.5)
LR Tests				
Chi-2 Model 2 versus Model 1		5.02*		11.82***

Notes: Robust standard errors, clustered by parent firm, in parentheses; ***,**,* indicate significant at the 1, 5 and 10 percent levels.
US is the reference group for the Home Country Dummies.

Figure 1: Predicted Values of the Probability to Conduct Foreign R&D in Function of Countries' Academic Research Strength and the Science Orientation of Firms in Period 1.

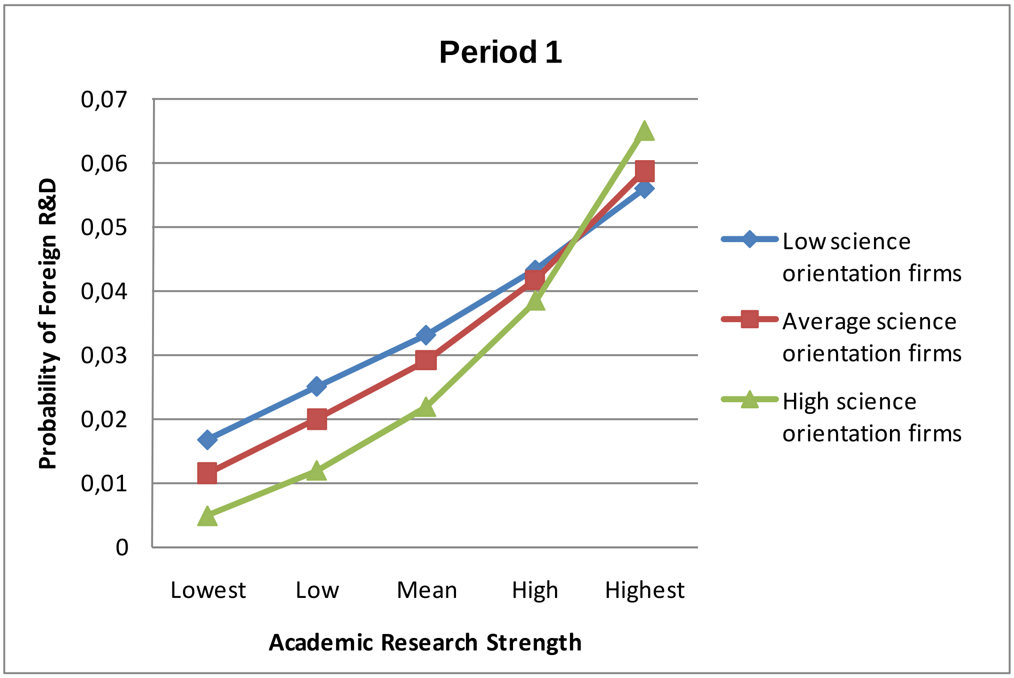
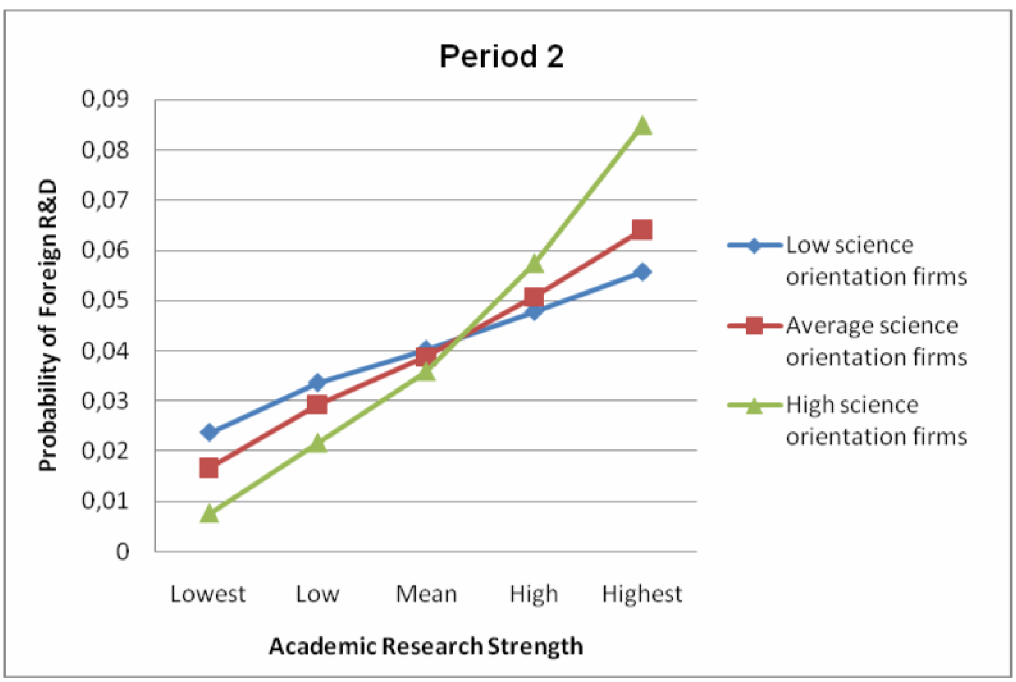


Figure 2: Predicted Values of the Probability to Conduct Foreign R&D in Function of Countries' Academic Research Strength and the Science Orientation of Firms in Period 2.



Appendix 1: Technology Classes and Main Technology Classes

	Technology Class	*Technology Main Class*
1	Electrical machinery and apparatus, electrical energy	Electrical engineering
2	Audio-visual technology	Electrical engineering
3	Telecommunications	Electrical engineering
4	Information technology	Electrical engineering
5	Semiconductors	Electrical engineering
6	Optics	Instruments
7	Analysis, measurement and control technology	Instruments
8	Medical technology	Instruments
9	Nuclear engineering	Instruments
10	Organic fine chemistry	Chemistry, Pharmaceutical
11	Macromolecular chemistry, polymers	Chemistry, Pharmaceutical
12	Pharmaceuticals, cosmetics	Chemistry, Pharmaceutical
13	Biotechnology	Chemistry, Pharmaceutical
14	Agriculture, food chemistry	Chemistry, Pharmaceutical
15	Chemical and petrol industry, basic materials chemistry	Chemistry, Pharmaceutical
16	Chemical engineering	Process engineering and special equipment
17	Surface technology, coating	Process engineering and special equipment
18	Materials, metallurgy	Process engineering and special equipment
19	Materials processing, textiles & paper	Process engineering and special equipment
20	Handling, printing	Process engineering and special equipment
21	Agricultural and food processing, machinery and apparatus	Process engineering and special equipment
22	Environmental technology	Process engineering and special equipment
23	Machine tools	Mechanical engineering and machinery
24	Engines, pumps and turbines	Mechanical engineering and machinery
25	Thermal processes and apparatus	Mechanical engineering and machinery
26	Mechanical elements	Mechanical engineering and machinery
27	Transport	Mechanical engineering and machinery
28	Space technology, weapons	Mechanical engineering and machinery
29	Consumer goods and equipment	Mechanical engineering and machinery
30	Civil engineering, building and mining	Mechanical engineering and machinery

Appendix 2: Correlation Table

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Foreign R&D (Dependent Variable)	1																
2	Academic Research	0.20	1															
3	Technological Strength	0.27	0.67	1														
4	Technological Strength in Related Fields	0.25	0.71	0.89	1													
5	IPR Protection	0.15	0.19	0.56	0.60	1												
6	GDP per Capita	0.14	0.22	0.57	0.62	0.78	1											
7	Market Size	0.18	0.53	0.50	0.51	0.25	0.18	1										
8	Engineering Wage	0.11	0.01	0.44	0.47	0.77	0.80	0.14	1									
9	European Host Country	0.06	0.09	0.33	0.36	0.48	0.46	-0.05	0.30	1								
10	Language Similarity	0.08	0	0.03	0.03	0.10	0.01	0.02	0.04	-0.08	1							
11	Geographic Distance	-0.12	-0.07	-0.14	-0.16	-0.12	-0.16	-0.04	-0.05	-0.31	-0.09	1						
12	Firm's Science Orientation	-0.01	0.03	-0.01	-0.03	-0.01	-0.02	-0.18	0.02	0	-0.02	0.13	1					
13	Firm's Technological Strength	0.23	0.01	0.03	-0.02	0	0	-0.03	-0.01	-0.01	-0.01	-0.02	0.07	1				
14	Firm's Total Patents	0.10	0.03	0	0.02	0.01	0.01	-0.05	-0.02	0	-0.02	-0.02	0.09	0.41	1			
15	International R&D Experience	0.08	0.04	0.02	0.03	0.01	0.02	0.03	-0.04	-0.01	0.03	-0.07	-0.06	0.19	0.48	1		
16	Firm's Age	0.05	0.02	0	0.01	0	0.01	0.12	0	0	-0.03	-0.16	-0.22	0.10	0.24	0.39	1	
17	Manufacturing or Sales Subsidiary	0.16	0.21	0.25	0.25	0.18	0.14	0.28	0.14	-0.01	0.09	-0.16	-0.04	0.07	0.16	0.14	0.12	1

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