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The Drivers of Foreign Direct Investment into Research and Development: An Empirical Investigation

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This paper examines the determinants of foreign direct investment (FDI) in research and development laboratories by 32 multinational enterprises in the pharmaceutical and electronics industries. The paper applies a dichotomous set of motives for FDI. Results from an econometric analysis of 136 laboratory investments show that relative market size and relative strength of a country's science base determine whether FDI in research and development is carried out in order to exploit existing firm-specific advantages, or in order to build up new firm-specific advantages. This holds true in similar form for Japanese, European and U.S. firms and across the two industries.

INTRODUCTION

Foreign direct investment (FDI) in research and development (R&D) is not a new phenomenon. Cantwell (1995) has found that in the 1930s the largest European and U.S. firms carried out about 7 percent of their total R&D abroad. However, after WWII this figure has been rising steadily to reach about 19 percent in the 1980s. The increasing presence of foreign firms' R&D sites has often left domestic firms concerned about effects of these investments on inter-firm competition. Furthermore, it has left governments concerned about the welfare effects of FDI in R&D on host nations (OECD, 1996; US-Government, 1992).

A number of researchers have examined FDI in R&D. Existing studies can be grouped into three categories: Detailed case studies (Behrman and

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Fischer, 1980; Hakanson and Zander, 1988; Herbert, 1989; Ronstadt, 1977, 1978), survey-based studies (Cantwell, 1989; Dalton and Serapio, 1993, 1995; Florida, 1997; Hakanson and Nobel, 1993a, 1993b; Kenney and Florida, 1994; Mansfield, Teece and Romeo, 1979), and other large sample/overview studies (Dunning, 1994; Hirschey and Caves, 1981; Howells, 1990a; Kogut and Chang, 1991; Mowery and Teece, 1992; Patel and Pavitt, 1991; Pearce, 1989; Westney, 1993). Cheng (1993) noted the growing importance of cross-border R&D activities and suggested that additional research should be done on why firms internationalize their R&D.

The case studies focus on processes and motives of FDI. They find that there are differing motives, and that the role and level of autonomy of R&D sites can, but need not evolve over time (Hakanson and Zander, 1988; Herbert, 1989; Ronstadt, 1978). The survey-based studies and other large sample studies focus on different structural aspects of FDI in R&D. Like the case studies, these studies generally focus on FDI in R&D into one country or from one country. The countries studied are the United States, Japan, Sweden and the United Kingdom. The findings suggest that a higher level of autonomy of local subsidiaries coincides with a higher level of FDI in R&D (Hirschey and Caves, 1981; Mansfield, Teece and Romeo, 1979; Pearce, 1989). Some findings suggest that a high level of local R&D is carried out primarily to adapt products to local markets (Hakanson and Nobel, 1993b; Howells, 1990a). More recent studies point out that firms also invest in R&D abroad to gain access to local knowledge (Florida, 1997). From the literature it is evident that there are multiple motives for FDI in R&D. However, the structure and relative importance of these motives is unclear. Also, only few studies examine multiple countries, and only few of the large-sample studies explicitly model firm behavior by examining macro-level variables of target and source countries (Kogut and Chang, 1991; Pearce, 1989; Pugel, Kragas and Kimura, 1996).

This paper makes use of an original database that was built up through a systematic survey of all laboratory investments carried out by 32 of the world's largest pharmaceutical and electronics firms (Kuemmerle, 1999). The database comprises detailed evidence regarding motives and locations of FDI in R&D. The database, in combination with macro-economic data on source countries and target countries of investments, permits an innovative look at FDI in R&D.

The paper examines forces that drive firms' decisions for locating R&D sites in foreign countries. Specifically, the paper develops a dichotomous set of motives for FDI in R&D, namely, that firms invest in R&D sites abroad either to augment a firm's existing stock of knowledge, or to exploit this stock of knowledge within the firm's boundaries. Section 2 develops the set of motives. Section 3 examines potential stimuli for laboratory investments abroad and proposes an empirical test. Section 4 presents and discusses empirical results. Section 5 concludes, suggesting some implications for managers and public policy makers.

HOME-BASE-EXPLOITING AND HOME-BASE-AUGMENTING FDI IN R&D

A considerable part of the existing FDI literature argues that FDI occurs when firms seek to exploit firm-specific

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capabilities in foreign environments. Once a firm realizes it has a capability that could be used to satisfy demand in a foreign country, it will evaluate different options for exploiting this capability (Dunning, 1958; Dunning, 1995; Hymer, 1976). The firm will generally face a decision between setting up its own subsidiary in the foreign country, or contracting out the activity in question. Rivoli and Salorio (1996) show that the decision between FDI and contractual agreements to exploit firm-specific capabilities should evaluate not only the direct benefits of FDI, but also the option value of deferring an FDI commitment under conditions of high uncertainty.

Several researchers have described the importance of FDI in R&D for exploiting firm-specific capabilities in foreign environments (Bartlett and Ghoshal, 1990; Hakanson, 1990; Vernon, 1966). They argue that as local demand grows increasingly sophisticated, local R&D facilities are useful in helping a firm to adapt existing products better to local needs. As firms establish manufacturing facilities abroad and assign increasingly complex products to them, R&D sites in close proximity to factories are necessary. These sites support the transfer of knowledge and prototypes from the firm's home location to actual manufacturing. The importance of co-locating some firm R&D efforts with manufacturing operations and local demand has been described not only in the international business literature, but also in industrial geography (Fors, 1997; Howells, 1990a, 1990b) and technology management literature (Clark and Fujimoto, 1991; Hayes and Wheelwright, 1988; Nonaka and Takeuchi, 1995; von Hippel, 1988).

In contrast to the capability-exploiting motive for FDI in R&D, a number of researchers have pointed out more recently that particularly in the case of R&D, the main driver for FDI might be a firm's need to augment its knowledge base (Cantwell, 1989; Florida, 1997; Howells, 1990b; Kogut and Chang, 1991; Pugel, Kragas and Kimura 1996). Wesson (1993) has made a similar argument for FDI in general. These researchers argue that specific nations and specific regions within them might be particularly advantageous locations for R&D facilities because of potential spillovers from existing and productive R&D organizations. Such organizations include research universities, publicly funded research institutes and innovative competitors. Additional externalities that make a country attractive for FDI in R&D are created by supporting industries offering these inputs, such as firms that provide laboratory equipment, maintenance firms or specialized laboratory testing services.

A number of researchers have studied the relationship between growth of geographical agglomerations (clusters) of firms and the competitive position of nations (Krugman, 1991; Porter, 1990; Scherer, 1992). These researchers found that differences in the character and size of national innovation systems (including higher education, intellectual property laws, public funding for research, venture capital structures) shape the nature of externalities within a cluster. As a result, nations differ in their attractiveness for FDI in R&D.

A firm's geographical expansion of R&D sites generally originates from a base location in which product strategies are developed and core technologies are developed and updated. This central R&D location is generally close

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to the firm's headquarters or divisional headquarters. We will call this location home base, and the two types of FDI mentioned above, home-base-exploiting (HBE) and home-base-augmenting (HBA). It is important to note that the distinction between HBE and HBA FDI in R&D is strictly instrumental for the larger purpose of understanding how firms make their decisions for locating knowledge production sites, and for transferring knowledge within the firm's boundaries.

Having established the conceptual distinction between HBE and HBA FDI in R&D, we can ask why one should expect geographical separation of the two types of laboratories. It is *prima facie* efficient to carry out both types of activities at the same time and in the same place, since intensive information must be exchanged between HBE and HBA activities. For both types of R&D activities to be carried out in geographically separate overseas locations, one of two conditions must hold. Either scope diseconomies exist between the two types of laboratories, or the two types of laboratories are subject to strongly different locational pulls.

This paper examines whether the two types of laboratories are subject to different locational pulls. Since country level variables are used to identify different locational pulls, the empirical analysis will, in fact, test a complementary set of propositions: First, divergent locational pulls are strong enough to offset the available scale/scope economies of coupling HBE and HBA FDI in R&D; and second, national endowment variables can explain the multinational enterprise's choice of location given a choice between HBE and HBA laboratory investments.

One can hypothesize that different characteristics of a country would induce a firm to establish either an HBA or an HBE laboratory. Home-base-exploiting laboratories will be more probable if a foreign country offers important market opportunities that the foreign firm seeks to convert into high profits. Such market opportunities justify the high, fixed up-front investments and operating expenses of a laboratory site that adapts products to local demand. Home-base-augmenting laboratories, however, will be more probable if the size of a country's knowledge base is large *and* the quality of this knowledge base is high. Firms who seek to augment their home base are looking for a large pool of qualified engineers and scientists from which they can select those most suited to the firm's needs. At the same time, however, firms seek to tap into knowledge pools of very high quality, since the ideas that the firm hopes to generate and capture through HBA investments are intended to provide the foundation for the long-term future profitability of the whole firm.

Beyond the theoretical argument above, on which the distinction between HBE and HBA FDI is based, it is interesting and reassuring that the concept of HBE and HBA R&D sites was easily understood by managers (mainly senior R&D managers) when they were asked in the empirical survey to distinguish laboratory investments according to these two categories.

DATA AND MODEL

In an attempt to understand the global dispersion of R&D activities, we collected data on all locations at which 32 pharmaceutical and electronics companies carry out R&D activities. These two industries were chosen because a number of independent surveys identified

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them as the most active in FDI in R&D (MIRI, 1991; OECD, 1993), followed by the chemical, vehicle and machinery industries.

We decided to study FDI in R&D through wholly or partially owned laboratories rather than through research agreements[1] between firms and universities for three reasons. First, FDI in R&D requires a longer-term commitment to a localized research effort by the firm than does a research agreement. Second, the preliminary field study on research agreements revealed that the six firms in the pilot study sample allocate only about 1-3 percent of their total R&D expenditures abroad to research agreements with universities. Thus, in order to understand the full dimension of the international dispersion of firm R&D, it seemed necessary to study FDI. Third, laboratory sites are relatively easy to identify as units of analysis.

Furthermore, we wanted to collect data for a sample of the world's largest firms domiciled in major industrialized countries. We hypothesized that large firms domiciled in these countries would be particularly active in establishing R&D sites abroad since these firms are at the forefront of knowledge creation and have probably exhausted the advantages of a single location.[2] Furthermore, we were interested in whether patterns of laboratory establishment would differ across major industrialized countries. Because of resource limitations we targeted the five largest companies in each industry and country, resulting in a target sample size of 30 companies.

The data collection effort included archival research, a detailed questionnaire and at least one, normally two or three, interviews with senior managers in R&D and top line at each of the companies. In the electronics industry, the survey focused on electronics companies that produced technologically intensive goods such as computer hardware, electronic components and telecommunications equipment. In the data gathering effort, R&D investments related to other products than these were excluded wherever possible. In the pharmaceutical industry only ethical drug activities were included. Larger companies were approached first. Whenever a company declined to cooperate on the survey, the next largest company in size was approached. Fortunately, only five companies declined to cooperate in the empirical survey, and were replaced by the next largest companies. The actual sample of 32 companies resulted from the fact that additional electronics companies in the United States and Japan agreed to participate in the survey.

The 32 companies are displayed in Table 1, which shows that the size of the six cells is roughly equal, except for electronics firms in Germany. Of the few large electronics firms that could be identified in Germany, only two, Siemens and Bosch, were willing to cooperate. Therefore, two French firms, Alcatel and Bull, and a Dutch firm, were added to the sample. This decision was based on the insight that home base and governance structures of these three European countries (Germany, France and the Netherlands) are at least somewhat comparable. It seems worthwhile to note that the companies in the sample are among the largest industrial enterprises in the world: 19 of the 32 companies in the sample are part of the 1994 Fortune Global 100 companies, respectively. Table 2 shows that Japanese pharmaceutical firms had markedly lower sales and international

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sales ratios than all other firms. This might be explained by the fact that Japanese pharmaceutical firms enjoyed a high level of protection of their domestic market in the past. As a consequence, they started their international expansion much later than all other firms in the sample.

Unit of Analysis, Dependent Variable and Hypotheses

The unit of analysis is the laboratory classified at the time it was established. An R&D laboratory is defined as a specific site that carries out R&D activities according to the OECD definition (OECD, 1981). While sites are sometimes expanded by adding new and organizationally different activities, at least as far as laboratories abroad are concerned, most of the sites represent a homogenous organizational and functional entity. More specifically, less than 5 percent of the laboratory sites in the sample changed their primary orientation from HBA to HBE, or vice versa. This finding

TABLE 1
COMPANIES IN SAMPLE

	Pharmaceuticals	Electronics	Total
United States	Merck Pfizer Eli Lilly Bristol Myers-Squibb (4)	IBM General Electric Xerox Motorola Texas Instruments Hewlett-Packard (6)	(10)
Japan	Fujisawa Yamanouchi Eisai Chugai (4)	Matsushita NEC Fujitsu Toshiba Sony Canon Sharp Kyocera (8)	(12)
Germany	Bayer Hoechst BASF Schering Byk-Gulden (5)	Siemens Bosch (2)	(7)
France		Alcatel Bull (2)	(2)
Netherlands		Philips (1)	(1)
Total	(13)	(19)	(32)

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TABLE 2
DESCRIPTIVE DATA ON FIRMS IN SAMPLE

	1994 Sales ($ billion)	R&D/Sales (1994)	International Sales/Sales (1994)
Electronics			
U.S. firms	12.6	8.1%	61.8%
Japanese firms	17.3	7.3%	33.0%
European firms	13.4	7.5%	48.0%
Pharmaceuticals			
U.S. firms	4.9	13.7%	39.8%
Japanese firms	2.1	11.7%	19.4%
European firms*	26.5	6.6%	77.5%
Total	18.2	9.4%	38%

* Includes chemicals.

is contrary to Ronstadt (1978) who found that in several cases the role of laboratories abroad expanded over time. One possible explanation for our findings could be that since Ronstadt's study, coordination costs among geographically dispersed lab sites have decreased. Firms in Ronstadt's sample found it advantageous to carry out both types of activities at the same location, while firms in our sample preferred to establish sites with a different focus at more beneficial locations within the same target country.

A logistic regression procedure is used where the dependent variable in all regressions is HBACAT. This variable takes the value 1 if by the time of its establishment a laboratory was primarily an HBA laboratory and 0 if the laboratory was primarily an HBE laboratory. The variable was collected through a questionnaire that contained a detailed explanation of the concepts of home base, HBA and HBE. The questionnaire was generally completed by senior R&D managers who knew the firm's laboratories well.

Interviews were scheduled once the questionnaire had been returned and the responses concerning the dependent variable were verified. Typically, the senior R&D manager who had completed the survey, as well as a top level line manager with a good understanding of the company's technology strategy, were interviewed. Furthermore, in 11 of the 32 companies we conducted interviews with either the CEO or the board member in charge of R&D. Finally, we interviewed either a top scientist involved in actual scientific discovery activity at the time and/or a senior financial manager responsible for resource allocation for R&D, depending on these managers' availability. Responses concerning the dependent variable were cross-checked across all interviewees in the company if applicable. The combined approach of questionnaires and interviews resulted in a detailed picture of the firms' technology strategies, geographical dispersion of R&D and R&D management across borders.

The dependent variable was collected as a continuous variable (percent of personnel in the laboratory working on HBA

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versus HBE projects) by means of a questionnaire and through subsequent interviews. The distribution of this continuous variable (shown in Table 3) was strongly bi-modal, and we coded it as a bi-modal variable that takes the value 1 if more than 50 percent of personnel worked in an HBA function. Only 4 labs carried out approximately equal amounts of HBA and HBE work. Statistical analyses were run with the small number of cases around the 50 percent mark in either category, without any major change of the signs of covariates or significance level of results. We also ran all regressions as ordinary-least-square regressions using the dependent variable in its original continuous form. Results were very similar to results from the logistic regression analysis.

Altogether, there are 156 sites abroad in the sample, i.e., 4.9 sites abroad per company. 76% (n=118) of the laboratories are located in just five countries: The United States (n=48), the United Kingdom (n=24), Japan (n=19), Germany (n=14), and France (n=13). Altogether, there are 19 target countries (i.e., countries in which labs were built) in the sample.[3] It becomes evident that FDI in R&D is essentially a phenomenon that takes place among the most advanced economies in the world. Laboratories outside these countries represent exceptions. Generally, there were either very specific factor endowments or host country subsidies, or very long-term market objectives or political pressure by the host government present in the less developed countries that induced the companies in the sample to invest abroad. Home-base-augmenting laboratories on average were 3.6 years younger than HBE labs (significant at 5% level). Firms seem to first exploit their home base location before investing in HBA locations.

Foreign direct investment in R&D is

TABLE 3
FOCUS OF LABORATORIES
(% OF ACTIVITY DEDICATED TO HBA, AS OPPOSED TO HBE, ACTIVITY)

	0% HBA	1-33% HBA	34-67% HBA	68-99% HBA	100% HBA	Total
Number of sites	81	11	4	4	56	156

TABLE 4
DESCRIPTIVE DATA ON LABORATORY SITES IN SAMPLE

Type	Number of Sites	Date of Establishment (avg.)	Count of Laboratory Locations (laboratories abroad only) United States	Japan	Europe	Other
HBA Electronics	36	1985	15	3	16	2
HBA Pharmaceutical	24	1986	9	3	10	2
HBE Electronics	62	1982	21	8	18	15
HBE Pharmaceutical	34	1980	3	5	22	4
Total	156	1983	48	19	66	23

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actually as much a regional phenomenon as it is a national phenomenon. In the United States, investments are heavily clustered in the Northeast and on the West Coast. In Japan, most foreign labs are located in the Tokyo area.[4] This underlines the conjecture that a comparative regional analysis within nations would be the most appropriate way for studying the issue if data at that level were available.

Finally, the average size (i.e., the number of full-time researchers and support staff) of HBA and HBE laboratories did not differ much (104 versus 95 employees; a t-test (1% level) revealed no statistically significant difference). This gives us reason to believe that HBA and HBE FDI in R&D require similar resource commitments, at least as far as laboratory sites as units of analysis are concerned.

Independent Variables

The independent variables are proxies for characteristics at the national level. Several of these proxies have been suggested in prior research (Cantwell, 1989; Florida, 1997; Howells, 1990b; Kogut and Chang, 1991; Porter, 1990). First, we sought proxies that would identify differences in the home bases of highly developed countries. Second, we sought proxies that would be available for all source countries and target countries for all the years in which laboratories were built (the first laboratory abroad in the sample was built in 1957). These challenges limited the range of possible variables. It was particularly difficult to find variables that were available for all the countries in question. In fact, for some of the laboratories that were constructed in the 1960s, and for some laboratories in newly industrialized countries, little data were available, thus excluding 20 out of 156 cases from the statistical analysis.

The first of the independent variables, R&DD, is defined as the difference between gross expenditures on R&D divided by gross domestic product in the target country, and gross expenditures on R&D divided by gross domestic product in the source country by the time of the laboratory's establishment. This measure is a proxy for the relative strength of the target country's science base. Gross expenditures on R&D consist of the sum of public spending on R&D and business expenditures on R&D. Since both public and private R&D expenditures in a country create spillovers that are potentially accessible for foreign firms, a relatively higher amount of potential spillovers should induce a foreign firm to invest in the respective country, provided the firm judges its capabilities of appropriating such spillovers as sufficient.[5] We hypothesize that the higher R&D spending in the target country relative to the source country of FDI, the higher the probability that a given laboratory at the time of establishment will be an HBA laboratory. Thus, we expect this variable to have a positive sign.[6]

Also included in the analysis is the difference in revealed comparative advantage between the target country and the source country. COMPADVD is the difference between industry-specific exports of the target country and industry-specific exports of the source country normalized by industry-specific world exports in the year of laboratory establishment.[7] Revealed comparative advantage can be viewed as a proxy for the relative advantage of a nation's industry over the same industries from other nations. High values for revealed comparative advantage can be driven by

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exports of high volumes of low cost products or by exports of lower volumes of high-priced, technologically advanced products, or by a mix of both. Arguably, in the two technologically intensive industries included in this study, a high value for revealed comparative advantage is determined by high-priced and technologically advanced products.

Therefore, we expect that the higher the comparative advantage of the target country relative to the source country in the year in which the site was established, the larger the technological advantage of the target country over the source country, and the higher the probability that a given laboratory investment will be HBA rather than HBE. Since the comparative advantage variable, COMPADVD, is highly correlated with the R&D spending variable, R&DD, the two variables were tested in different models.

The third independent variable is a proxy for a country's scientific excellence. A number of R&D managers stated in their interviews that when their firm considered establishing an HBA research site, it evaluated not only the target country's current overall public and private commitment to R&D, or the target country's state of education, but also the presence of outstanding individual researchers. In many cases the firm did not have direct ties to these researchers, but expected indirect spillovers, such as a larger number of bright graduate students being attracted to the location and country in question if there was a "stellar" researcher present. The firm expected that these graduate students would become accessible as human resources for the firm. Furthermore, some firms expected increased public R&D spending in the region and country in question because of an outstanding researcher's lobbying power.

Once again, it would be desirable to have data at the regional level while controlling for countries. Unfortunately, this is not the case; therefore, a variable at the national level will be used: Nobel Prizes in hard sciences (physics, chemistry, medicine). For about 15 of the 156 investments in the sample, Nobel Prizes were specifically considered by decision makers within the firm. Evidence from these cases was used when constructing the variable.

Location decisions for corporate laboratory investments are not so much triggered by the nationality of the Nobel Prize winner, but by the country and home institution where research activity for the Prize was carried out. This information is normally known within the firm's investment committee for R&D, which usually includes outstanding senior scientists. Firms value recently awarded Nobel Prizes more highly, apparently for two reasons. First, firms prefer to access recently created basic scientific knowledge because the probability of transforming this knowledge into competitive advantage for the firm is higher than with older knowledge, which might have already been appropriated by other firms. Second, firms seem to have an organizational memory that members draw upon when making investment decisions. Based on the field study, the length of this memory seems to be around five years. Events that occurred less than five years prior to the investment decision are specifically considered in the decision process, while earlier events entered decisions to establish R&D sites as trends rather than as specific events.

One could argue that by the time Nobel Prizes are awarded, the discovery for which they are awarded is outdated; hence future, rather than past, Nobel Prizes should be considered as a variable

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for this analysis, since excellent scientific research is widely recognized before the award is granted. However, Nobel Prizes are given for basic research, while firms carry out primarily applied R&D in the sense of the OECD's definition (1981). Since the "migration" of knowledge from basic to applied research takes time, it is possible that corporate investments in Nobel Prize-level research locations is, in fact, "just in time." In any case, over the last two decades Nobel Prizes were often awarded to relatively young scientists quite soon after the seminal discovery had been completed and documented.

The variable NOBEL is the difference between the cumulative number of Nobel Prizes that were awarded over the last five years for scientific discovery activity carried out in the target country (which in many cases is not identical with the nationality of the prize winning researcher), and the source country controlling for industry. The field study indicated that electronics firms expect spillovers primarily from Nobel Prizes in physics, while pharmaceutical firms expect spillovers from Nobel Prizes in both medicine and chemistry. Therefore, for laboratory investments in the electronics industry the cumulative number of Nobel Prizes in physics in the target country and source country (over the five previous years) was recorded; for labs in the pharmaceutical industry the average of the cumulative number of Nobel Prizes in chemistry and medicine (over the previous years) was recorded. Split prizes were recorded as fractions. The Nobel Prize variable can be expected to have a positive influence on the probability to establish an HBA laboratory.

Also tested was a variable PCTTEDD, which is the difference between the percentage of the population with a tertiary education in the target country and the source country in the year of establishment of the laboratory. The success of HBA R&D activities depends heavily on the quality of human resources available in a potential target country relative to the source country. The success of HBE R&D is dependent on a combination of local labor inputs of a certain minimum quality and on organization-specific knowledge of the researchers and engineers in the local laboratory. This knowledge, rather than the formal education of the research personnel, will contribute to a speedy and efficient local adaptation of products whose core technology was created in other countries. Because of the relatively higher importance of the level of formal education of human resources for the success of HBA research, the hypothesis is that the higher the percentage of population with a tertiary education in the target country relative to the source country the higher, the probability that a given laboratory investment will be HBA rather than HBE.

The fourth independent variable (GNPD) is the absolute difference in GNP of target country and source country in US$ millions. This variable is used as a proxy for measuring the relative attractiveness of the target country concerning HBE investments by the firm domiciled in the source country. The larger the absolute size of a national market relative to the size of the firm's home market, the higher the probability that the firm will make considerable up-front investments that it later hopes to recuperate through volume sold in that market.

Investments into HBE laboratories for local adaptation and peripheral creation are essentially such up-front investments. One would expect that the larger the difference in GNP, the lower the probability that a newly established lab is an HBA lab. Ideally, one would have preferred to

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collect a variable that more precisely reflects the relative market size for products of the pharmaceutical and electronics industries. While such variables are available for some industrialized countries, particularly the United States, they are not easily available for others, and for almost no country back to the 1960s. The difference in GNP can be expected to have a negative influence on the probability that a given laboratory is an HBA laboratory.

Finally, a number of control variables were included. In Model 1, we included a dummy to distinguish the two industries. In Model 2 we included firm dummies for all but one firm. PHARMA takes a value 1 in the pharmaceutical industry and 0 for the electronics industry. The propensity of pharmaceutical companies to carry out HBE research abroad can be expected to be somewhat higher because the pharmaceutical industry is more influenced by national public regulators. Pharmaceutical companies might, therefore, face an informal requirement to carry out substantial adaptive R&D in some foreign countries. For example, in the past Japan has urged foreign pharmaceutical companies not only to replicate clinical tests for new drugs in Japan, but also to "consider" different dosage or application forms. This often required the establishment of local development sites. While no such requirement exists in France, a number of companies in the sample found that the presence of an HBE laboratory in France was conducive to speedier approval procedures.

A dummy for the date of laboratory establishment was also included. In principle, time dummies should be included for each year to capture time-varying inducements of laboratory establishment. Given the small number of observations, however, this approach was not feasible. Instead, extraneous information was used to pick a single time dummy. ESTDAT>84 takes the value 1 if the laboratory was established or acquired after 1984. The year 1984 was selected as the cut-off point because it represents the starting point of a marked increase in the establishment of laboratories abroad in general and by Japanese firms in particular. 58 percent of all laboratories were set up after 1984. ESTDAT>84 is expected to have a positive influence on firm's propensity to establish HBA laboratories. The reason is that the firms in the sample, probably with the exception of Japanese pharmaceutical firms, started their international expansion long before setting up laboratories, by establishing foreign sales subsidiaries, and later manufacturing facilities in major foreign markets. It can be expected that in the course of establishing an international network of R&D sites in other industrialized countries, firms first sought to exploit existing advantages through HBE laboratory sites; then, having gained an understanding of the characteristics and strengths of the local R&D environment, they considered the establishment or acquisition of HBA sites.[8] In addition, Models 1, 1a and 1b include fixed effect variables for Europe (EUROPE) and Japan (JAPAN), with the United States as the baseline. The European firms are mostly German firms (seven out of 10 firms).

Table 5 presents predicted signs for covariates, descriptive statistics and correlation coefficients. The bivariate correlation coefficient between percentage of population with tertiary education and the Nobel Prize measure is very high (.90), which makes a joint entry into the regression not meaningful. Therefore, these two variables were entered in separate regressions. The same applies for the variables for difference in R&D spending and revealed comparative advantage.

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TABLE 5
PREDICTED SIGNS OF COVARIATES

Logistic Regression. Dependent Variable: HBACAT (Home-base augmenting = 1)

Covariate	Predicted Sign	Description
JAPAN	control	=1 if home country Japan.
EUROPE	control	=1 if home country Europe.
PHARMA	-	=1 if pharmaceutical industry.
ESTDAT>84	+	=1 if laboratory was established after 1984.
R&DD	+	(gross expenditures on R&D in target country/GDP target country) - (gross expenditures on R&D in source country/GDP source country).
COMPADVD	+	revealed comparative advantage target country - source country (by industry).
GNPD	-	GNP target country - GNP source country
NOBEL	+	number of relevant Nobel Prizes target country - source country.
PCTEDD	+	percentage of population with tertiary education target country - source country.

Summary of Descriptive Statistics

Variable	Mean	Std.Dev.	Min	Max	Valid N
HBACAT	.3846	.4881	0	1	156
JAPAN	.4487	.4989	0	1	156
EUROPE	.2115	.4097	0	1	156
PHARMA	.3718	.4848	0	1	156
ESTDAT>84	.5769	.4956	0	1	156
R&DD	-.4794	.7006	-2.976	.63	139
COMPADVD	-.0554	.0992	-.2390	.2420	133
GNPD	-368.7	2318.47	-6292	4339	148
NOBEL	-.0599	2.2107	-4.4	4	156
PCTEDD	2.6309	25.0457	-50	48.81	143

Correlation Coefficients
(117 observations)

	HBACAT	JAPAN	EUROPE	PHARMA	ESTD>84	R&DD	COMP-ADVD	GNPD	NOBEL	PCTTEDD
HBACAT	1.0000									
JAPAN	-0.1079	1.0000								
EUROPE	0.2343	-0.5955	1.0000							
PHARMA	0.0112	-0.2586	0.2262	1.0000						
ESTD>84	0.0098	0.4568	-0.2598	-0.0585	1.0000					
R&DD	0.2358	0.0409	0.1567	-0.1567	-0.0269	1.0000				
COMPADVD	0.1136	0.0120	-0.0100	0.2765	0.0034	0.3195	1.0000			
GNPD	0.0094	0.3110	0.2201	-0.1967	0.0703	0.5200	0.0323	1.000		
NOBEL	0.1781	0.5672	0.1228	-0.0933	0.2578	0.4101	0.0923	0.7896	1.0000	
PCTTEDD	0.0747	0.6584	0.0113	-0.1754	0.3117	0.3310	-0.0157	0.7934	0.9009	1.0000

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RESULTS

Tables 6, 7, 8 and 9 show the results of logistic regressions. Model 1 was built by first introducing regional dummies and industry dummies and then, subsequently, difference in R&D spending, difference in GNP, difference in number of Nobel Prizes. Model 1a is identical with Model 1, except that the Nobel Prize variable was replaced by the population with tertiary education variable. Model 1b is identical with Model 1, except that the variable for R&D spending differences was replaced by the variable for difference in revealed comparative advantage. Model 2 replaces the industry dummies and regional dummies by firm dummies and otherwise follows the strategy of Model 1.[9]

In all regressions the variables for differences in R&D spending, revealed comparative advantage, GNP, Nobel Prizes and population with tertiary education have the expected sign. The improvement in chi-square that results

TABLE 6
LOGISTIC REGRESSION - MODEL 1

DEPENDENT VARIABLE: HOME BASE AUGMENTING
LOGISTIC REGRESSION WITH SOURCE COUNTRY AND INDUSTRY DUMMIES

	MODEL 1.1	MODEL 1.2	MODEL 1.3	MODEL 1.4	MODEL 1.5	MODEL 1.6
			COEFFICIENTS AND SIGNIFICANCE			
SOURCE COUNTRY DUMMIES						
EUROPE	1.455***	1.462***	.948*	1.452**	.090	.098
JAPAN	.498	.493	.144	.636	-1.612*	-1.823**
INDUSTRY DUMMY		-.030	.100	.019	-.258	-.255
R&DD			.837***	1.215***	1.106***	1.181***
GNPD				-.00023**	-.00059***	000579***
NOBEL					.797***	.781***
ESTABLISHMENT DATE DUMMY						.563
CONSTANT	-1.024	-1.013	-.307	-.499	.712	.479
LOG LIKELIHOOD	-98.91	-98.90	-86.44	-83.33	-76.88	-76.19
MODEL CHI-SQUARE	10.07	10.07	16.00	18.93	31.82	33.19
PROB > CHI2	.007	.018	.003	.002	.000	.000
PSEUDO R2	4.84%	4.85%	8.47%	10.20%	17.15%	17.89%
N	156	156	139	136	136	136
LIKELIHOOD RATIO TEST (CHI2 AND P >CHI2). (COMPARISON TO PREVIOUS MODEL)		01	24.93***	6.22**	12.89***	1.37

NOTES:
REGIONAL VARIABLES: JAPAN (=1 IF HOMECOUNTRY JAPAN), EUROPE (=1 IF HOME COUNTRY EUROPE), UNITED STATES AS BASE MODEL.
PHARMA = 1 IF PHARMACEUTICAL INDUSTRY, 0 IF ELECTRONICS INDUSTRY.
ESTABLISHMENT DATE DUMMY = 1 IF LABORATORY WAS ESTABLISHED AFTER 1984.
R&DD = (GROSS EXPENDITURE ON R&D IN TARGET COUNTRY/GDP OF TARGET COUNTRY) - (GROSS EXPENDITURES ON R&D IN SOURCE COUNTRY/GDP OF SOURCE COUNTRY).
GNPD = GNP TARGET COUNTRY - GNP SOURCE COUNTRY.
NOBEL = NUMBER OF RELEVANT NOBEL PRIZES TARGET COUNTRY - SOURCE COUNTRY.

* SIGNIFICANT AT 10% CONFIDENCE LEVEL.
** SIGNIFICANT AT 5% CONFIDENCE LEVEL.
*** SIGNIFICANT AT 1% CONFIDENCE LEVEL.

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from including these variables in the regressions is always significant at least at the 5% confidence level, in most cases at the 1% level. The pseudo R^2 statistic is 17.9% and 26.1% for Models 1 and 2, respectively. Therefore, most of the covariates in the model seem to be non-trivial for the explanation of a firm's propensity to establish HBA laboratory sites. It should be noted, however, that given the multi-collinearity between difference in GNP and Nobel Prizes (.79), and between difference in GNP and the tertiary education variable (.79), independent confirmation of all hypotheses can not be claimed.

In comparison to the variable for revealed comparative advantage, the variable for differences in R&D spending is more highly significant (the former is significant at the 5% level, the latter variable in most cases significant at the 0.1% level). The difference in R&D spending might be a better predic-

TABLE 7
LOGISTIC REGRESSION - MODEL 1A

Dependent Variable: Home Base Augmenting
Logistic regression with source country and industry dummies (use of PCTEDD instead of NOBEL as covariate)

	Model 1a.1	Model 1a.2	Model 1a.3	Model 1a.4	Model 1a.5	Model 1a.6
			Coefficients and significance			
Source country dummies						
Europe	1.455***	1.462***	.948*	1.452**	.583	0.566
Japan	.498	.493	.144	.636	-1.030	-1.280
Industry dummy		-.030	.100	.019	-.223	-.250
R&DD			.837***	1.215***	1.279***	1.307***
GNPD				-.00023**	-.00059***	-.00058***
PCTTEDD					.052**	.051**
Establishment date dummy						.540
Constant	-1.024	-1.013	-.307	-.499	.422	.233
Log Likelihood	-98.91	-98.90	-86.44	-83.33	-77.46	-76.8
Model Chi-square	10.07	10.07	16.00	18.93	22.17	23.48
Prob > chi2	.007	.018	.003	.002	.001	.001
Pseudo R2	4.84%	4.85%	8.47%	10.20%	12.52%	13.26%
n	156	156	139	136	129	129
Likelihood ratio test (chi2 and p >chi2) (comparison to previous model)		0.01	24.93***	6.22**	11.74***	1.31

Notes:
Regional variables: JAPAN (=1 if homecountry Japan), EUROPE (=1 if homecountry Europe), United States as base model.
PHARMA = 1 if pharmaceutical industry, 0 if electronics industry.
Establishment date dummy = 1 if laboratory was established after 1984.
R&DD = (gross expenditure on R&D in target country/GDP of target country) - (gross expenditures on R&D in source country/GDP of source country).
GNPD = GNP target country - GNP source country.
PCTTEDD = percentage of population with tertiary education target country - source country.

* significant at 10% confidence level.
** significant at 5% confidence level.
*** significant at 1% confidence level.

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tor for the fact that a given laboratory site is home base augmenting: The difference in R&D spending represents an input into the production function that is geared towards improving the country's knowledge base relative to other countries, while revealed comparative advantage represents a country's relative strength in exports, which could be caused by factors other than a superior stock of knowledge.

In comparison to the tertiary education variable, the Nobel Prize variable leads to a larger improvement in chi-square and is more highly significant. Differences in the number of Nobel Prizes might be a better predictor for the propensity of firms domiciled in industrialized countries to establish HBA laboratories in other industrialized countries; the underlying national science structures that generate scientific excellence such as Nobel Prize-winning discovery attract firms more strongly to invest in these countries than a generally well-educated population. Differences in share of population

TABLE 8
LOGISTIC REGRESSION - MODEL 1B

Dependent Variable: Home Base Augmenting
Logistic regression with source country and industry dummies (use of COMPADVD instead of R&DD as covariate)

	Model 1b.1	Model 1b.2	Model 1b.3	Model 1b.4	Model 1b.5	Model 1b.6
			Coefficients and significance			
Source country dummies						
Europe	1.455***	1.462***	1.721***	1.961***	.732	.710
Japan	.498	.493	0.208	0.415	-1.654*	-1.578**
Industry dummy		-.030	-0.472	-0.483	-0.692	-0.681
COMPADVD			4.505**	4.895**	4.406**	4.388**
GNPD				-0.00005	-0.00043***	-0.0004***
NOBEL					0.786***	0.775***
Establishment date dummy						0.243
Constant	-1.024	-1.013	-0.344	-0.505	0.522	0.421
Log Likelihood	-98.91	-98.90	-82.86	-80.66	-74.44	-74.32
Model Chi-square	10.07	10.07	15.93	16.38	28.84	29.08
Prob > chi2	0.007	0.018	0.003	0.005	0.000	0.000
Pseudo R2	4.84%	4.85%	8.77%	9.22%	16.23%	16.36%
n	156	156	156	130	130	130
Likelihood ratio test (chi2 and p >chi2) (comparison to previous model)		0.01	32.08***	4.39**	12.46***	0.24

Notes:
Regional variables: JAPAN (=1 if homecountry Japan), EUROPE (=1 if homecountry Europe), United States as base model.
PHARMA = 1 if pharmaceutical industry, 0 if electronics industry.
Establishment date dummy = 1 if laboratory was established after 1984.
COMPADVD = revealed comparative advantage of target country - revealed comparative advantage of source country.
GNPD = GNP target country - GNP source country.
* significant at 10% confidence level.
** significant at 5% confidence level.
*** significant at 1% confidence level.

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with tertiary education might be more applicable to both HBA and HBE investments than differences in number of Nobel Prizes.

The firm dummies in Model 2 were not significant (at the 10% level). No specific firm had a significantly higher propensity to invest in HBA FDI in R&D than other firms (10% level). This might indicate the similarity of multinational companies domiciled in industrialized countries.

The industry dummy was never significant, but it had the expected negative sign in the final versions of Model 1 (1.5, 1.6). Thus, while pharmaceutical firms seem to have a higher propensity to establish HBE laboratories for regulatory reasons, this effect might be partially outweighed by the need for HBE investments in the electronics industry for manufacturing or marketing reasons.

The inclusion of regional dummies did not lead to a significant improvement of the chi-square statistic in the full versions of Model 1, 1a and 1b (at the 10% confidence level). Firms from the three different countries/regions do not have different propensities to conduct HBA versus HBE R&D abroad. This is a rather interesting result. Over the past 15 years, Japanese firms have attracted considerable attention from researchers in international business,

TABLE 9
LOGISTIC REGRESSION - MODEL 2

Dependent Variable: Home Base Augmenting
Logistic regression with firm dummies

	Model 2.1	Model 2.2	Model 2.3	Model 2.4	Model 2.5
	Coefficients and significance				
Firm dummies	n.m.	n.m.	n.m.	n.m.	n.m.
R&DD		.876**	1.364***	1.053**	1.106**
GNPD			-.00028**	-.00089***	-.0008***
NOBEL				1.186***	1.187***
Establishment date dummy					1.414**
Constant	-.154	.229	.778	-.794	-1.668*
Log Likelihood	-86.26	-75.86	-72.24	-64.81	-62.49
Model Chi-square	15.1	20.41	24.56	39.42	44.06
Prob > chi2	.955	.813	.652	.090	.05
Pseudo R2	8.05%	11.86%	14.53%	23.32%	26.07%
n	142	128	125	125	125
Likelihood ratio test (chi2 and p >chi2) (comparison to previous model)		20.81***	7.25***	14.86***	4.64**

Notes:
R&DD = (gross expenditure on R&D in target country/GDP of target country) - (gross expenditures on R&D in source country/GDP of source country).
GNPD = GNP target country - GNP source country.
NOBEL = Number of relevant Nobel Prizes target country - source country.
Establishment date dummy = 1 if laboratory was established after 1984.
* significant at 10% confidence level.
** significant at 5% confidence level.
*** significant at 1% confidence level.

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some of whom argue that these firms differ from Western firms in terms of corporate governance structures. Our research shows how these Japanese firms are similar to Western firms in terms of actual investment decisions made.

In a separate analysis, location decisions among multiple target countries were explored for five major target countries through a conditional logit choice model. Findings support the analysis carried out above. For HBA laboratories, firms tend to choose countries where the science base is relatively well developed; for HBE laboratories, they tend to choose countries with large markets (Kuemmerle, 1998).

In general, the results concerning the regional, industry and firm dummies can be interpreted as evidence for the similarity of behavior of multinational corporations rather than as evidence for differences among these corporations. Finally, the dummy for the date of laboratory establishment had the expected positive sign in all models, but was significant only in Model 2.[10] These results indicate that firms establish HBE laboratories first and HBA laboratories later in their international expansion.

CONCLUSION

A considerable body of literature has characterized the multinational enterprise as a global private profit maximizer. Only a few studies have examined the R&D activities of multinational enterprises. R&D outside of the firm's home base has generally been described as a means to utilize and exploit proprietary firm technology within the firm boundaries.

Based on recent work about the organization of multinational enterprise, this study started with the assumption that there might be a dichotomous set of motives for the global dispersion of R&D. When testing this framework, this study found that a firm's propensity to invest in HBA R&D activities abroad rises with the relative commitment to R&D of private and public entities in the target country, as well as with the quality of the human resource pool and with the level of scientific achievement in relevant sciences. The propensity to invest in HBE activities increases with the relative attractiveness of the target country's market. The analysis also revealed that firms from different home countries differ little in their propensity to invest in either type of R&D activity abroad. Finally, there was only weak evidence for differences in firm behavior across industries. While these results were quite robust in a sensitivity analysis, they should nevertheless be regarded with some caution because the proxies might not be optimal. However, considering the large number of factors other than those accounted for in this analysis, the explanatory power of the model seems to be quite high.

The findings suggest that when investing in R&D abroad, firms seek *different types* of spillovers from the national and local environment in which they invest. It would be precipitous, however, to assume that foreign firms investing in local R&D facilities are free riders. Foreign firms also create spillovers for the local environment because R&D sites provide employment and learning opportunities for local researchers. While this argument might apply more strongly to foreign firms' HBA R&D sites, it also applies to HBE sites.

Our findings have important implications for managers. First, our research shows that FDI in R&D is a phenome-

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non that has increased rapidly over the last years. Second, the notion of HBA and HBE R&D sites offers an innovative approach to international R&D management that is predicated on the analysis of knowledge flows across borders. Managers can use this framework to structure their planning processes, and to communicate them effectively to employees. Third, this paper suggests a number of country-specific characteristics that managers can compare when searching for a new R&D site. Fourth, the paper shows that multinational firms domiciled in different home countries follow similar stimuli when setting up R&D sites abroad. This insight could be useful for anticipating competitor behavior in a firm's strategic planning process.

Our findings also have implications for public policy. First, public policy makers should develop realistic attitudes as to what kind of FDI they can attract to their nations and regions within them in the short run. For newly developed countries, it will most probably be easier to attract a firm to invest in HBE FDI in R&D, especially if a particular firm already operates manufacturing facilities in that country or region. Over time, spillovers from HBE R&D sites might contribute to the creation of a sufficient science base for local firms and institutions of higher learning to prosper, perform and finally attract HBA FDI in R&D. Thus, the findings indirectly suggest that all other things being equal, creating an attractive national and local environment for HBA FDI in R&D might be more resource intensive and time consuming than creating a suitable environment for HBE FDI in R&D. Second, our research implies that it is important for public policy makers in industrialized countries to consider that even seemingly small inter-country differences in public and private commitment to R&D can determine what kind of R&D foreign firms will carry out in these countries.

Further research should focus on rigorously applying the concept of HBA versus HBE investments by multinational enterprises to other firm functions, such as manufacturing and distribution. In addition, there are a number of interesting questions concerning the nature of the evolution of intra-firm knowledge flows across national borders as firms expand the number of R&D sites abroad.

NOTES

1. While this research focuses on laboratory sites, the author does not want to dismiss the importance of research agreements as alternative means to acquire or exchange technology on a more limited basis. In fact, a further study will explore the relationship between wholly or partially owned laboratories and research agreements between firms in the near future by combining the data set used for this study with a database on research agreements.

2. The study found this relationship to hold in general. For all firms in the sample, the correlation between 1993 net sales (in US$) and the number of laboratory sites abroad was .771.

3. It should be noted here that FDI in R&D can be carried out either through greenfield investments, through acquisitions or through joint ventures. Depending on the firm's existing stock of knowledge and its future needs, the firm might prefer one of these three forms over the other two. The empirical analysis takes into account all three forms of FDI. In the empirical study it was found that investing firms preferred

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greenfield investments (79%) over acquisitions (15%) and joint ventures (6%). The analysis included only acquisitions and joint ventures that were carried out primarily to gain control over R&D capabilities of the acquired organization or joint venture partner.

4. In Japan, the Tokyo region seems to attract almost all FDI in R&D in the electronics and pharmaceuticals industries, while the Osaka and Nagoya regions attract at least some laboratory sites in the machinery and vehicles industries.

5. One would have preferred to use industry level government and industry R&D spending for this analysis. Unfortunately, these data were difficult to obtain for some countries and were not available for others. However, an analysis with data available at the industry level revealed a high correlation between gross expenditures for overall R&D and expenditures for R&D in the two industries. Thus, there is reason to assume that gross expenditures on R&D reflect public and private commitment to R&D in the electronics and pharmaceutical industries quite accurately.

6. The study also collected a variable for business expenditures on R&D only. The hypothesis was that in the above regression the coefficient of gross expenditure on R&D (= GERD, which includes public R&D) would be higher than the coefficient of business expenditure on R&D (BERD) because firms who invest in HBA laboratories seek not only spillovers from private industry (which might be ambiguous spillovers anyway), but also spillovers from publicly funded research institutions. GERD and BERD were highly correlated (.91). Both variables were included separately in the statistical analysis and it was found that GERD led to a higher level of statistical significance and to a higher value of the coefficients in all versions of models 1 and 2.

7. For the electronics firms in the sample, the average of the UN Trade Statistics (revision 1) codes 714 (data processing equipment), 722, 723, 724, 725, 7293 (telecommunications and sound processing equipment, electrical machinery, circuits, transistors) were used. For the pharmaceutical firms, data for code 5417 (medicaments) were used.

8. Most companies in the sample had established sizable international sales and manufacturing presence before investing in R&D sites abroad. (The survey covered close to all laboratory sites of the firms in the sample, and some information about the firms' sales and manufacturing presence). On average, the firms in the sample achieve 38 percent of their overall sales outside of their home country (SD 21%). Furthermore, the data show that few labs, if any, have changed their role from HBE to HBA or vice versa. Also, there is a very low survivor bias in the sample: Out of 156 sites, 2 sites were shut down or strongly reduced in size.

9. All the residual plots of the full versions of all three models were inspected, and no important deviation from the assumed logistic distribution function could be detected. Furthermore, a sensitivity analysis was conducted by examining high leverage points. In the final versions of models 1 and 2, a number of two and two observations, respectively, with high leverage were found. Most of these observations were HBE laboratories in countries with relatively small markets at the time of laboratory construction (India, Australia, Taiwan). Exclusion of these sites lead to minor changes in the size of regression coefficients, but did not

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change signs or significance levels. While the laboratories in question are somewhat exceptional cases, they are part of the phenomenon of FDI in R&D, and there seems to be no reason to exclude them definitely from the sample.

10. Alternative specifications with three and four categories of establishment dates (e.g. <1975, 1975-1984, 1985-1994) were also examined. The results support the general finding that earlier laboratories tended to be HBE rather than HBA.

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