ELSEVIER

Research Policy 26 (1997) 85–103

research policy

The globalization of R&D: Results of a survey of foreign-affiliated R&D laboratories in the USA

Richard Florida *

Center for Economic Development, H. John Heinz III School of Public Policy and Management, Carnegie Mellon University, Pittsburgh, PA 15213, USA

Final version received 1 November 1996

Abstract

This paper examines the globalization of innovation and the phenomenon of foreign direct investment (FDI) in research and development. To do so, it draws from a survey of foreign-affiliated R&D laboratories in the United States. While the literature on foreign direct investment has emphasized the role of markets in driving off-shore investments, the main conclusion of this research is that the globalization of innovation is driven in large measure by technology factors. Of particular importance is the objective of firms to secure access to scientific and technical human capital.

1. Introduction

Foreign direct research and development (R&D) investment has grown rapidly over the past decade and innovation has become increasingly global in nature. Multinational enterprises have established an increasing number of R&D laboratories in offshore locations. The United States is a particularly interesting case from which to examine the phenomenon of R&D globalization, since it has attracted a large amount of foreign R&D spending and a considerable number of R&D laboratories affiliated with foreign parent companies. Foreign corporations spent nearly $15 billion on R&D in the United States in 1994, accounting for more than 15% of total U.S. industrial R&D expenditures.

A number of studies have examined foreign direct R&D investment (Ronstadt, 1977, 1978, Mansfield et al., 1979, Cantwell, 1989, Pearce, 1989, Wortman, 1990, Archibugi and Michie, 1995, Mowery, 1997, Howells, 1990, Casson, 1991, Mowery and Teece, 1992, 1993, Westney, 1992, Dalton and Serapio, 1993, 1995, Florida and Kenney, 1994, Dunning and Narula, 1995). Generally speaking, the literature suggests that foreign direct R&D investment is a relatively small component of overall scientific and technical activities, and that it tends to be oriented to foreign markets and support offshore manufacturing investments. Several recent studies, however, suggest that the rapid growth of foreign direct R&D investment, particularly in the United States, reflects corporate efforts to harness external scientific and technological capabilities and generate new technological assets (see Dunning and Narula, 1995, Kummerle, 1997).

Despite the rapid growth of foreign direct R&D investment, little is known about the actual activities, organization, and performance of foreign-affiliated R&D laboratories. Several studies have examined

* E-mail: rflorida@aol.com.

PII S0048-7333(97)00004-8

the motivations of foreign-affiliated research facilities in the United States, mainly through interviews and case studies of small samples of firms (see Herbert, 1989, Dalton and Serapio, 1993, 1995, Angel and Savage, 1994, Florida and Kenney, 1994, Reid and Schriesheim, 1996). For the most part, however, existing studies rely heavily on government statistics which provide useful data on foreign R&D spending but do not cover other aspects of foreign-affiliated laboratories, or on case studies of small numbers of foreign-owned laboratories from which it is hard to generalize.

This article examines the scope, activities, performance, and organization of foreign-affiliated R&D laboratories in the United States, reporting the findings from a national survey. The survey identified more than 200 foreign-affiliated R&D laboratories, and achieved a response rate of 90%.

This article seeks to make five key contributions. First, we address the issue of the motivations and activities of foreign-affiliated R&D laboratories. We distinguish between two principal types of foreign direct R&D investment, market- and technology-oriented. The foreign direct investment (FDI) literature emphasizes the role of demand-side factors in motivating FDI in R&D, particularly support of offshore markets and manufacturing (Vernon, 1966, 1977, Abernathy and Utterback, 1978, Utterback, 1989). According to this literature, FDI in R&D is motivated principally to adapt and tailor products for foreign markets and provide technical support to offshore manufacturing operations. Several studies note the pursuit of so-called global localization strategies for manufacturing and product development by multinational corporations (Porter, 1986, 1990). Recent studies, however, note the importance of science and technology factors or supply-side factors in motivating FDI in R&D. Several studies note that foreign R&D investment represents a strategy to maintain competitive advantage by generating new technological assets and capabilities (see particularly Cantwell, 1989, Casson, 1991, Howells and Wood, 1993, Dunning and Narula, 1995, Archibugi and Michie, 1995, Kummerle, 1997, Mowery, 1997). We argue here that these technology-oriented or supply-side factors are increasingly important in motivating and shaping FDI in R&D. The findings of statistical analyses examining the relationship between R&D spending and R&D activities indicate that two technology-oriented factors—gaining access to science and technology and developing links to the scientific and technical community—are the only two factors that are significantly associated with R&D spending by sample laboratories. We thus suggest that foreign R&D laboratories are increasingly adopting what we refer to as a technology-oriented posture in their activities.

Second and related to this, we argue that gaining access to human capital, specifically scientific and technical talent, is the central element of the motivations and strategies of foreign-affiliated R&D laboratories in the sample. The findings of statistical analyses of the relationship between R&D spending and the activities of sample laboratories support this view, indicating that the laboratories in our sample focus their resources on attracting high quality scientific and technical talent as simply opposed to monitoring U.S. technology, gaining access to U.S. science, customizing products, or supporting offshore markets.

Third, we suggest that foreign direct R&D investment is a heterogeneous process, with considerable variation in the nature and activities of foreign-affiliated R&D laboratories across industrial sectors. While the FDI literature treats FDI in R&D as more or less homogeneous, the literature on technical change suggests considerable variation in innovative activity by industry and technology. The technical change literature notes that the sources of innovation differ substantially by industry and technical field, with some sectors drawing heavily from basic science and others linked more closely to applied activities (Rosenberg, 1982, Nelson, 1986, 1993 Rosenberg and Nelson, 1994). We find that there are considerable inter-industry differences in FDI in R&D. In particular, we find that the biotechnology sector differs in important respects from other sectors, being motivated by and oriented to science and technology activities to a greater degree. This may reflect high-level U.S. scientific capabilities in this field and the close links between basic science and commercial technology in this industry.

Fourth, this study addresses the managerial and organizational dimensions of foreign-affiliated R&D laboratories. In this regard, we suggest that a central feature of international R&D management involves balancing the need for overall corporate coordination with the autonomy required for innovation and creativity. Studies of international R&D management note the difficulties associated with coordinating offshore R&D subsidiaries (see Bartlett and Ghoshal, 1989, Howells and Wood, 1993, Kenney and Florida, 1993, Florida and Kenney, 1994). While foreign R&D subsidiaries require linkages to other corporate units to coordinate their activities, complex reporting requirements and the perception of external control can have negative impacts both on innovative performance and on the ability to recruit and attract high-quality scientific and technical human capital (see Davis-Florida, 1996a,b, 1997 on the organizational factors that affect recruitment of scientific and technical talent). We find that the foreign-affiliated laboratories in our sample possess considerable autonomy in developing and managing their scientific and technical agendas.

Fifth, this study considers the internal organization of foreign R&D laboratories, focusing, in particular, on the question of whether or not foreign R&D laboratories seek to transfer management and organizational systems associated with R&D laboratories of the parent company in the home country. Here, we find that the foreign R&D laboratories in our sample make little apparent effort to transfer the management and organizational systems associated with R&D laboratories in their home country. Instead, we find that sample laboratories tend to emulate and learn from prevailing U.S. approaches to R&D organization and management. In this respect, the management strategies associated with foreign R&D subsidiaries differ from manufacturing where studies note transfer and replication of key organizational practices to offshore locations.

2. Study design

This study is based on a national survey of foreign-affiliated R&D laboratories in the United States. The sample was composed of independent or stand-alone foreign-affiliated laboratories in the United States engaged principally in research, development, and design activities, and, as such, does not include research, development, and design activities conducted by other organizational units, such as corporate divisions or manufacturing plants. An initial sample of 393 foreign-affiliated R&D laboratories was compiled from government sources, including a 1993 study by the Department of Commerce (Dalton and Serapio, 1993) and directories of R&D facilities, such as the *Directory of American Research and Technology*. The sample was checked against other available lists of foreign-affiliated R&D laboratories available at the time it was developed, and appeared to be the most comprehensive listing available; compare, for example, the 393 listings in the sample to the 255 listings in a 1993 U.S. Department of Commerce study (Dalton and Serapio, 1993). [1]

Screening interviews eliminated 153 establishments from the survey: 88 were not involved in any research, development, or design activities, another 33 were duplicate listings, and 32 could not be located. The screening phase resulted in an overall response rate of 91.9%, including establishments that could not be located. Only one of the 361 contacted units refused to participate in the screening phase for an adjusted response rate of 99.7%, for establishments that could be located.

The survey was administered by telephone by the Center for Survey Research at the University of Massachusetts–Boston. The survey produced a total of 186 completed interviews. The survey identified 33 additional establishments which were ineligible, either because they were duplicates ($n = 4$), not foreign-owned ($n = 4$), or were not engaged in research, development, or design ($n = 21$). This resulted in a response rate of nearly 90% (89.9%) of the eligible units (186 completions of 207 eligible units). In the following analysis, the survey data are arrayed according to 13 specific technology fields and a broader grouping of four technology sectors (e.g. electronics, automotive technology, chemicals

[1] A revised and updated version of the Commerce Department study lists 645 foreign-affiliated R&D establishments (Dalton and Serapio, 1995). However, there are reasons to believe this may be an over-statement. It is likely that a substantial fraction of these establishments are not actually involved in R&D, particularly since the sample for this study and the Commerce Department list are drawn from largely the same sources.

and materials, and biotechnology and pharmaceuticals). [2]

3. Scope and activities of sample laboratories

The key characteristics of sample laboratories are outlined in Table 1. Sample laboratories ($n = 207$) spent $5.14 billion on R&D in 1994. [3] This is equivalent to roughly 7% of U.S. company-financed industrial R&D ($76.9 billion as of 1993; National Science Board, 1993, p. 371), and more than a third (35.2%) of the of $14.6 billion in total R&D by foreign corporations in the United States (Dalton and Serapio, 1995, p. 7). [4] Sample laboratories employed an estimated 65,800 workers, 25,000 scientists and engineers, and 7400 doctoral-level researchers in 1994, equivalent to roughly two-thirds of all R&D workers (105,200) employed by foreign companies in the United States (Dalton and Serapio, 1995, p. 8). [5] The respondents averaged $26.6 million in total R&D spending, roughly $100,000 ($102,946) in R&D spending per employee, and employed an average of 286 people, including 181 scientists and engineers, and 33 doctoral-level researchers.

The foreign-affiliated R&D laboratories in our sample devoted $396 million (8%) to basic research, $1.8 billion (36%) to applied research, and $3 billion (58%) to product development. Thus, sample laboratories appear to be slightly more research intensive than U.S. industrial R&D as a whole which devoted 4.2% of total R&D effort to basic research, 23.5% to applied research, and 72.2% to product development in 1993 (National Science Board, 1993, pp. 333–336). This is not surprising, since the U.S. figure includes the R&D resources of manufacturing plants and corporate administrative units, while the figure for sample laboratories is limited to stand-alone R&D laboratories.

Table 1
Key characteristics of sample laboratories

Number of laboratories	207
R&D spending (millions)	$5140
Basic research (millions)	$396
Applied research (millions)	$1830
Product development (millions)	$2976
Total employment	65,800
Scientists and engineers	25,000
Doctoral-level researchers	7400

Source: Florida (1995).

Previous research notes that a handful of technologically advanced nations account for the overwhelming bulk of foreign R&D spending in the United States (Dalton and Serapio, 1995, pp. 11–12). More than half of respondents in our sample (53.8%, $n = 100$) had European parents, while 45.2% ($n = 84$) were affiliated with Asian parents. The only respondents outside these two regions were two Canadian affiliates. Sample laboratories affiliated with European parent companies accounted for more than three-quarters of R&D spending and two-thirds of employees. [6] Sample laboratories with British parents ranked first in R&D spending ($1.03 billion), followed by Japan ($737 million), France ($708 million), Germany ($699 million), and Switzerland ($656 million).

The foreign-affiliated R&D laboratories in our sample are concentrated in four broad industrial sectors (biotechnology and pharmaceuticals, chemicals and materials, electronics, and automotive technology) and 13 sub-sectors. The biotechnology and pharmaceutical sector is the largest of the four sectors, with more than 60% of reported R&D spending ($2.5 billion) as Table 2 shows. Pharmaceuticals is the largest of the 13 sub-fields ($1.44 billion) followed by biotechnology ($851 million), telecommu-

[2] This grouping system is similar, though not identical, to the standard industrial classification system and is based on the specific technology fields reported by respondents.

[3] This estimate is an extrapolation which takes into account non-respondents to this question. The 186 foreign-affiliated R&D establishments that responded to the survey spent $4.1 billion on R&D in 1994.

[4] The latter includes R&D spending by all corporate units, including manufacturing divisions and plants, and spending by foreign companies at U.S. universities, and other third party providers.

[5] Survey respondents employed a total of 52,395 workers, including 19,904 scientists and engineers, and 5875 doctoral-level researchers.

[6] These data represent reported spending by respondents only and are not estimated to account for the total sample population.

Table 2
R & D spending and employment by industry

Technology	Number	R & D spending ($ million)	Employment	R & D spending per employee ($)
Biotechnology / drugs	57	2,488	19,465	110,371
Biotechnology	30	851	6,630	120,010
Pharmaceuticals	14	1,444	7,320	150,713
Biomedical	13	193	5,515	46,373
Electronics	63	936	17,874	115,535
Computers and peripherals	8	74	2,378	87,875
Computer software	11	50	920	112,314
Audio-video equipment	9	257	4,071	315,543
Telecommunications	15	420	6,635	101,644
Semiconductors	13	97	3,200	80,705
Instruments	6	37	670	44,933
Chemical / materials	42	407	11,092	60,077
Chemical	37	399	10,150	67,914
Materials	5	8	942	9,921
Automotive	24	262	3,964	138,433
Manufacturing	18	151	3,218	107,961
Design	6	111	746	270,476

Notes: $N = 186$.
Source: Florida (1995).

nications ($420 million), chemicals ($399 million), audio-video equipment ($257 million), and biomedical technology ($193 million).

4. Technology and markets in foreign direct R & D investment

Both technology and markets play a role in motivating foreign investment in R&D. The literature to date has stressed the role of market or demand-side factors in motivating FDI in R&D. It is our contention that technology or supply-side factors are increasingly important in motivating and shaping the activities of foreign-affiliated R&D laboratories. To shed light on this issue, we distinguish between two principal types of FDI in R&D: market- and technology-oriented. Several studies note the increasing dependence of firms on external sources of technology (Roberts, 1994) and the development of global networks for both technology acquisition and monitoring (Bartlett and Ghoshal, 1989, Cantwell, 1989, Casson, 1991, Howells and Wood, 1993). Graham (1992) further distinguishes between two types of technology-driven strategies: *listening post*, the primary function of which is to monitor the scientific and technical capabilities of domestic firms and universities, and *generating station* which generates new scientific and technical knowledge. Some, however, continue to argue that offshore R&D investment accounts for a small share of total industrial innovation and that multinational corporations tend to retain advanced R&D capabilities in the home country (see Porter, 1986, 1990, Patel and Pavitt, 1991, Patel, 1995).

We begin by using the survey data to look at the relative importance of technology- versus market-oriented activities among sample laboratories (see Table 3). The survey asked a series of questions about the activities of sample laboratories. Respondents were asked to rate the importance of various activities on a three-point scale where 1 is not important and 3 is very important. The survey obtained information on five technology-oriented activities: (1) developing new product ideas, (2) developing new science and technology, (3) gaining access to technical talent, (4) obtaining information on U.S. science and technology, and (5) developing links to

Table 3
R&D activities of sample laboratories

Activity	Score	Very important (%)	Somewhat important (%)	Not important (%)	*N*
Developing new product ideas	2.84	86.8 (161)	11.3 (21)	2.2 (4)	186
Obtaining information on U.S. scientific and technical developments	2.70	71.5 (133)	26.9 (50)	1.6 (3)	186
Gain to scientific and technical talent	2.69	73.7 (137)	22.0 (41)	4.3 (8)	186
Customize products for U.S. market	2.56	67.6 (125)	20.5 (38)	11.9 (22)	185
Establish links to the U.S. scientific and technical community	2.48	53.2 (99)	41.4 (77)	5.4 (10)	186
Work with manufacturing facility in U.S.	2.40	59.4 (107)	21.1 (38)	19.4 (35)	180
Develop new science and technology	2.36	44.1 (82)	47.8 (89)	8.1 (15)	186

Note: Number of respondents in parentheses.
Source: Florida (1995).

the U.S. scientific and technical community; and on two market-oriented activities: (1) customizing products for the U.S. market and (2) working with the U.S. manufacturing facilities of the parent company. Generally speaking, the findings from the survey data indicate that both market- and technology-oriented activities are important, but that technology-oriented activities are, on balance, more important.

The three highest ranked activities suggest sample laboratories assume a technology-oriented posture. Survey respondents rated "developing new product ideas" as the highest ranked activity (2.84 score, 86.8% of respondents reporting very important). The second highest rated activity was "obtaining information on scientific and technological developments in the United States" (2.70 score, 71.5% very important). This was followed closely by "obtaining access to high-quality scientists, engineers and designers in the United States" (2.69 score, 73.7% very important). In addition, very small percentages of respondents (less than 5%) rated any of these three activities as not important.

Two technology-oriented activities ranked somewhat lower: "developing links to the scientific and technological community in the United States" (2.48) and "developing new science and technology" (2.36). It should be noted, however, that more than 90% of respondents listed the latter as somewhat important. These results suggest that sample laboratories are involved in both technology monitoring and technology development. Furthermore, technology development activities appear to revolve more around commercial technology rather than contributing to scientific and technical knowledge.

Market-oriented activities were reported to be somewhat less important to the overall activities of sample laboratories, according to the survey findings. "Customizing products for the U.S. market" ranked fourth (2.56 score, 67.6% very important), with nearly 12% of respondents reporting this as not important. Furthermore, respondents rated working with U.S. manufacturing facilities of the parent company quite low, with nearly one-fifth of respondents reporting not important. This is so even though 8 in 10 respondents report that their parent companies have manufacturing plants in the United States. The survey data thus provide only limited support for the notion that firms seek to link offshore R&D and manufacturing in accordance with a global localization strategy.

To shed further light on the relative importance of technology- versus market-oriented activities of foreign-affiliated R&D laboratories, we conducted regression analyses exploring the relationship between

R&D spending and the various activities of sample laboratories. This is particularly important since the differences in the overall rankings reported above are small, making it difficult to draw reliable conclusions on the relative importance of technology- versus market-oriented activities from these data alone. Specifically, we ran standard OLS regressions using log of R&D spending as the dependent variable and the activities of sample laboratories (see Table 3) as the independent variables. We examined the effect of the importance of each activity on R&D spending independently (model 1) and then did the same analysis controlling for the four industrial sectors (model 2). We also ran regressions exploring the effects of the importance of each activity on R&D spending (model 3) and again conducted the same analysis controlling for the four industrial sectors (model 4). The results of these models are summarized in Table 4. The findings here are robust, in that the coefficients for same independent variables are positive and significant in all four models. The findings of all four models indicate that two activities have large, positive, and significant associations with R&D spending: (1) gaining access to scientists and technologists, and (2) developing links to the scientific and technical community. For both activities, the effect is slightly smaller when controlling for all other activities. When additional variations of models 3 and 4 were run controlling for factors such as size, industry, and region, the findings were similar. Generally speaking, these findings support the conjecture that foreign R&D laboratories take on a technology-oriented posture to some degree. Furthermore, they suggest that human capital strategies are the central element of this technology-oriented posture. In fact, the findings indicate that human capital strategies are central to the overall activities of foreign R&D laboratories in our sample. In other words, these results suggest that sample laboratories are investing their resources to attract high-quality scientific and technical talent as opposed to monitoring U.S. technology, gaining access to U.S. science, customizing products, or supporting offshore markets. In fact, it can be argued that gaining access to high-quality scientific and technical human capital is relevant to each of those strategies.

We now turn to the question of whether the activities of sample laboratories vary by industry. As noted earlier, although the FDI literature treats FDI in R&D as more or less homogeneous, the literature on technical change suggests that there is likely to be variation in the nature and activities of foreign R&D

Table 4
R&D spending and activities for sample laboratories

Activity	Model 1	Model 2	Model 3	Model 4
Develop new project ideas	0.140	0.138	−0.117	−0.107
	(0.330)	(0.326)	(0.331)	(0.329)
Develop new science and technology	0.451	0.394	0.376	0.346
	(0.21)	(0.208)	(0.217)	(0.216)
Customize products for U.S. market	0.058	0.103	0.043	0.062
	(0.201)	(0.202)	(0.207)	(0.206)
Gain access to technical talent	0.826 *	0.802 **	0.694 **	0.689 **
	(0.238)	(0.236)	(0.262)	(0.281)
Obtain information on U.S. science and technology	0.449	0.375	−0.258	−0.282
	(0.273)	(0.273)	(0.319)	(0.318)
Develop links to U.S. scientific and technical community	0.714 **	0.644 **	0.629 *	0.563 *
	(0.216)	(0.219)	(0.247)	(0.249)
Work with U.S. manufacturing facilities of parent company	0.185	0.231	0.241	0.267
	(0.169)	(1.67)	(0.173)	(0.173)

Notes:
R^2 for model 3: 0.1334 *; R^2 for model 4: 0.1533 *.
* $p < 0.05$; ** $p < 0.01$.
Standard errors in parentheses.
Source: Florida (1995).

investment across fields of technology. Several studies have examined the motivations of foreign-affiliated research facilities in the United States, mainly through interviews and case studies of small samples of firms (see Herbert, 1989, Dalton and Serapio, 1993, 1995, Angel and Savage, 1994, Florida and Kenney, 1994). Although they are based on either highly aggregate data or on case studies, these studies provide some limited evidence to suggest that motivations for foreign R&D investment differ by industry. As noted previously, the literature on the innovation process suggests that the activities and orientations of R&D facilities vary according to the specific technological fields in which they work.

To shed light on this issue, we examined the differences in technology- versus market-oriented activities across the four industrial sectors: biotechnology, electronics, chemicals and materials, and automotive technology. The survey data inform a number of key findings here. First and foremost, large percentages of respondents across all industrial sectors reported developing new product technology as very important (87.7% of biotechnology, 87.3% of electronics, 85.7% of chemicals and materials, and 87.3% of automotive laboratories). Two additional findings emerge from the survey data with regard to industrial sector. On the one hand, large percentages of respondents in the biotechnology and pharmaceuticals sector rated technology-oriented activities as very important, including: developing new science and technology (54.4% versus 44.1% of the entire sample), obtaining information on U.S. science and technology (84.2% versus 71.5% of the entire sample), and establishing links to the U.S. science and technology communities (66.7% versus 53.2% of the entire sample). This is not surprising given the close dependence of commercial biotechnology on advances in basic science, particularly university science (Blumenthal et al., 1986a,b,Kenney, 1986, Levin et al., 1987, Klevorick et al., 1993). On the other hand, survey respondents in the automotive and chemical and materials sectors appeared to place more importance on market-oriented activities, such as supporting U.S. manufacturing operations and customizing products for the U.S. market. Three-quarters of respondents in both the chemicals and automotive sectors reported working with the U.S. manufacturing facilities of their parent company to be very important, compared with an average of 51.1% for the sample as a whole. In addition, 81% of respondents in the chemicals and materials sector and 79.2% of automotive industry respondents reported customizing products for the U.S. market as very important, compared with 57.9% of biotechnology respondents and 62.9% of respondents in the electronics industry. [7]

We ran a series of regression analyses to further probe relationships between R&D spending and laboratory activities across the four industrial sectors. We wanted to know if certain industries were more likely to emphasize technology-oriented activities, while other industries were more likely to emphasize market-oriented activities. Specifically, we ran separate regression analyses of the effects of laboratory activities on R&D spending for each of the four industrial sectors (automobiles, electronics, chemicals, and biotechnology). Again, we ran standard OLS regressions using log of R&D spending as the dependent variable and the activities of sample laboratories (listed in Table 3) as the independent variables. The results of these regressions, which are reported in Table 5, shed light on some important industry differences. Recall that the earlier analysis reported in Table 4 showed two activities to be significantly associated with R&D spending across all four industries: gaining access to technical talent and developing links to the U.S. scientific and technical community. The model for biotechnology, which was highly significant overall (at the 0.001 level), indicates that three factors were significantly associated with R&D spending in this sector. The two activities which were significant and positive in the overall model—gaining access to high-quality technical staff and developing links to the technical

[7] We also considered the patterns for the 13 specific technology fields. Here, a majority of respondents in the high-technology industries of pharmaceuticals (71.4%), software (63.6%), instruments (66.7%), and biotechnology (56.7%) ranked developing new science and technology as very important. However, large shares of respondents in audio-video equipment (88.9%) telecommunications (85.7%), and automotive technology (83.3%) ranked customizing products for the U.S. market as very important, and large shares of respondents from the chemical and automotive industries ranked support for manufacturing plants as very important.

Table 5
R&D spending and activities sample laboratories by industrial sector

Activity	Biotechnology $N = 48$	Electronics $N = 49$	Chemical and materials $N = 35$	Automotive $N = 16$
Develop new project ideas	−0.480	−0.260	−0.440	−0.736
	(0.589)	(0.593)	(0.562)	(1.752)
Develop new science and technology	1.189 **	0.369	0.229	−0.713
	(0.391)	(0.411)	(0.422)	(0.931)
Customize products for U.S. market	−0.467	0.902 **	−0.354	0.300
	(0.351)	(0.341)	(0.520)	(0.836)
Gain access to technical talent	1.342 **	0.986 *	0.017	0.715
	(0.457)	(0.439)	(0.647)	(1.247)
Obtain information on U.S. science and technology	0.516	0.003	−0.760	−0.047
	(0.729)	(0.450)	(0.615)	(1.454)
Develop links to U.S. scientific and technical community	1.185 **	0.179	0.549	−0.130
	(0.515)	(0.428)	(0.405)	(0.998)
Work with U.S. manufacturing facilities of parent company	0.250	0.195	0.922	0.031
	(0.297)	(0.289)	(0.486)	(0.812)
R^2	0.4721 ***	0.2511 *	0.2015	0.1533

Notes:
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
Standard errors in parentheses.
Source: Florida (1995).

community—were even more strongly associated with R&D spending among sample laboratories in the biotechnology industry. Furthermore, another activity—developing new science and technology—was found to have a large, positive, and significant association with R&D spending in the biotechnology sector. The findings for the biotechnology sector highlight the importance of scientific and technical activities and illustrate the importance of human capital factors to R&D spending by laboratories in this sector. The model for electronics indicates that two factors are significantly associated with R&D spending: gaining access to high-quality talent and customizing products for the U.S. market. In other words, these findings suggest that both technology- and market-oriented activities (or supply and demand factors) are important in this sector, and again emphasize the importance of human capital factors. The models for the two remaining sectors, automobiles and chemicals and materials, did not show significance for any activities in these two sectors. This result is likely to reflect the small number of observations in each of these sectors, leading to large standard errors. Put another way, the small number of observations leaves us unable to ascertain the relationship between R&D spending and activities for these two sectors.[8]

Taken together, these findings on the relationship between R&D spending and laboratory activities for the sample as a whole and for the four industrial sectors suggest the importance of technology-oriented activities in foreign direct R&D investment. These findings illustrate the importance of supply-side factors in motivating foreign R&D investment —factors which may to some extent be under-emphasized in the traditional literature on FDI—and suggest that the literature may to some degree overestimate the importance of demand-side factors (such as the size of local markets) in motivating FDIs in science and technology. Furthermore, this analysis highlights the importance of human capital to the investments and activities and foreign R&D laboratories and suggests that these objectives and activities are to some degree driven by human capital

[8] It is also worth pointing out that the model for the chemical and materials sector produced a very large positive effect (though at $p < 0.066$) for working with U.S. manufacturing facilities of the parent company. Recall also that three-quarters of respondents in this sector reported this activity as very important.

factors. This is the case across all fields, and appears particularly so in the field of biotechnology.

5. Innovative output and sources of innovation

We now turn to the innovative performance and sources of innovation for foreign-affiliated R&D laboratories. This is important since much of the academic literature treats foreign R&D laboratories as tending to be engaged in routine market support activities, while the recent popular literature suggests that foreign laboratories in the United States are intent upon monitoring U.S. scientific and technical developments and in some more extreme formulations are attempting to "steal" U.S. science and technology. Thus, it is important to know to what extent foreign-affiliated R&D laboratories are engaged in directly innovative activities such as patent and paper production, and what are the primary sources of innovation for these foreign-owned laboratories.

Before proceeding to our analysis of innovative outputs, a few caveats are in order. Economists and other experts have long noted the difficulties associated with measuring innovation outputs, including difficulties in constructing reliable and consistent outcome measures, lags in the innovation process, and the complexity of the process of technological change (see Cohen et al., 1996). For example, the propensity to patent or to copyright, and in some cases, even the frequency of publication, tends to vary widely by industry and technical field. Furthermore, it is particularly difficult to measure the more intangible aspects of innovation, such as new ideas and techniques which lead to improvements in products and processes. Despite these caveats, it remains useful to examine a series of direct and tangible innovative outputs, such as patent applications, patents, copyrights, and articles published in the open scientific and technical literature, for the laboratories in our sample. [9] Our principal objective here is not to determine the causes or determinants of the R&D performance and productivity of sample laboratories, nor is it to compare the R&D performance and productivity of sample laboratories with other innovative units. Rather, it is to examine whether or not the foreign R&D laboratories in our sample show some commitment to producing innovations, and thus to offer additional evidence of their taking on a technology-oriented posture as opposed to more traditional market-oriented activities.

The survey data indicate that sample laboratories are reasonably innovative, producing 2469 patent applications, 1068 patents, 669 copyrights, and 1812 published articles in 1994. Here, it is important to note that the 1068 patents reported by foreign-affiliated R&D laboratories in our sample is but a small fraction of the more than 30,000 U.S. patents granted to foreign corporations (National Science Board, 1993). It is more useful and informative, however, to control for differences in size when analyzing innovation outputs. This can be done by using performance measures which normalize output by the level of spending and/or employment. [10] The foreign-affiliated R&D laboratories in our sample generated 7.3 patents per $10 million in R&D spending and 12.8 patents per 100 scientists and engineers. Sample laboratories produced an average of 16 articles in the open scientific literature per $10 million in R&D expenditures. The rate of article production was 10.3 articles per 100 employees, 25.7 articles per 100 scientists and engineers, and 95.5 articles per 100 doctoral-level researchers, nearly one article per doctoral-level researcher per year for sample laboratories.

While it would be both interesting and useful to compare the output and performance of sample laboratories with that of U.S. R&D, the lack of comparable data on independent U.S. industrial laboratories makes such a comparison impossible. We can, however, use existing government data to compare the performance of the foreign R&D laboratories in our sample with that of all U.S. industrial R&D performers as a whole, including stand-alone laborato-

[9] It is worth noting that the survey data can directly link innovation output to particular facilities. These data thus allow more systematic comparison than the available government statistics which do not allow for comparison or analysis at the establishment level.

[10] The performance measures used here are modeled after those in Cohen et al., 1994; also see, Cohen and Florida, 1996, Randazzese, 1996).

ries, divisional laboratories, and factory-level units engaged in R&D. While the comparison is far from perfect, this analysis can provide a rough account of the relative innovative performance of foreign-affiliated R&D laboratories in our sample compared with all U.S. R&D performers.

Taking this caveat into account, the findings from this comparison are nonetheless interesting. The findings here provide additional evidence to suggest that the foreign-affiliated R&D laboratories in our sample are reasonably innovative and thus take on a technology-oriented posture to some degree. For example, the 7.3 patents per $10 million of R&D spending by sample laboratories compares with 4.7 patents per $10 million of company-financed industrial R&D for the U.S. as a whole. [11] The 12.8 patents per 100 scientists and engineers for sample laboratories compares with a rate of 4.9 patents per 100 scientists and engineers for U.S. industrial R&D. [12] Comparing article production highlights the fact that the foreign-affiliated laboratories in our sample are focusing at least some of their activities on the sort of research activities that lead to the production and publication of basic scientific discoveries. The 16 articles per $10 million in R&D spending produced by sample laboratories compares with a rate of 1.65 articles per $10 million of company-financed industrial R&D for the U.S. as a whole. [13] The rate of 10.1 articles per 100 scientists and engineers for sample laboratories compares with a rate of 1.65 articles per 100 scientists and engineers for U.S. industrial R&D. [14] Again, it is important to point out that this gap must be understood in the context of the fact that the U.S. figure is not limited to scientists and engineers working in R&D laboratories but also includes those working in manufacturing units and other corporate activities. That said, the figures for the foreign-affiliated R&D laboratories in our sample do provide reasonable evidence that those laboratories are focusing at least some share of their effort and activities on the production of innovative outputs, and thus provide some additional evidence of their adoption of a technology-oriented posture.

In addition to considering innovative output and performance, it is important to consider the sources of innovation on which foreign-affiliated R&D laboratories draw. As noted above, a number of commentators in the popular literature have recently argued that foreign R&D laboratories in the United States are orienting their activities to monitoring the U.S. scientific and technical environment and to "stealing" U.S. scientific and technical discoveries. Others have argued that foreign R&D laboratories are mere "listening posts" with the real source of ideas and innovations coming from laboratories back at home. Given these arguments, it is important to know the sources of innovation for sample laboratories. To what degree do these laboratories depend on in-house staff as a source of innovation? To what extent do new ideas and innovations emanate from scientists or managers back home? To what degree are U.S. institutions and organizations viewed as key sources of innovation? Answering these questions can provide a much better sense of whether or not foreign-affiliated R&D laboratories are orienting themselves to the development of new science and technology rather than extracting it from the U.S. environment or being passive implementers of ideas and strategies developed by parent company facilities in the home country.

To shed light on this issue, the survey collected detailed data on the various potential sources of innovation for foreign-affiliated R&D laboratories, including: in-house research staff, corporate executives, manufacturing plants, customers, suppliers, universities, joint venture partners, competitors, and consultants. We were particularly interested in the sources of innovation that can come from the industrial chain. Von Hippel (1988) noted the importance of customers and end-users as sources of innovation. Other studies suggest that corporate R&D laboratories may be declining as a source of innovation, as the importance of external sources (e.g. joint venture

[11] The U.S. average is based upon 36,074 patents and $76.9 billion in company-financed R&D (National Science Board, 1993, pp. 371, 455).

[12] The U.S. figure is for 1989—the latest date for which data can be obtained—35,734 industry patents and 726,000 scientists and engineers (National Science Board, 1993, pp. 309, 455).

[13] The U.S. data are for 1991—12,660 articles, $76.9 billion in company-financed industrial R&D (National Science Board, 1993, pp. 371, 428).

[14] The U.S. figure is for 1989—11,963 papers, 726,000 scientists and engineers (National Science Board, 1993, pp. 309, 428).

partners, suppliers, and universities) grows (see Roberts, 1994).

The sources of innovation for sample laboratories are summarized in Table 6. We defined innovations as "new project ideas"; and respondents were specifically asked to rate the importance of each as a source of new project ideas on a three-point scale, where 1 is not important and 3 is very important. As Table 6 shows, the leading source of project ideas for sample laboratories is in-house research staff (2.72 score), with nearly three-quarters of respondents rating this as very important. Respondents ranked customers as the second most important source of project ideas (2.54 score, 64.5 very important). Three additional groups were rated as "somewhat important": other R&D laboratories of the parent company (2.12), competitors (2.08), and joint venture partners (2.01). However, less than a third of respondents rated each of these sources as very important. Other sources ranked considerably lower as sources of new project ideas.

The findings further suggest that both manufacturing plants and suppliers are relatively unimportant sources of innovation for sample laboratories. Survey respondents ranked manufacturing plants of the parent company as the third least important source of new project ideas (1.66 score, 15% very important). Respondents rated suppliers even lower, with an overall score of 1.61. Nearly 50% (48.4%) of respondents rated suppliers as not important; and conversely, just 9.7% of respondents rated suppliers as a very important source of new project ideas. These findings suggest that even though a considerable fraction of foreign R&D activity appears to be related to supporting U.S. manufacturing, such activity primarily takes the form of technical support rather than developing new technological assets.

The findings also indicate that universities are a relatively unimportant source of project ideas (score = 1.81) for sample laboratories. More than a third of respondents reported that universities were "not important" as a source of new project ideas, and conversely, just 16% of respondents listed universities as very important. This is so even though more than two-thirds of respondents (67.6%, $n = 125$) reported that they engage in cooperative research with U.S. universities, and roughly half of respondents report that they recruit senior technical staff from

Table 6
Sources of innovation for sample laboratories

Source of new project ideas	Score	Very important (%)	Somewhat important (%)	Not important (%)	*N*
In-house research staff	2.72	73.1 (136)	25.8 (48)	1.1 (2)	186
Customers	2.54	64.5 (120)	25.3 (47)	10.2 (19)	186
Other R&D laboratories	2.12	29.6 (55)	53.2 (99)	17.2 (32)	186
Competitors	2.08	29.0 (54)	50.5 (84)	19.9 (37)	185
Joint ventures	2.01	23.1 (43)	54.8 (102)	22.0 (41)	186
Universities	1.81	16.1 (30)	48.9 (91)	34.9 (65)	186
Corporate executives in home country	1.71	13.5 (25)	43.8 (81)	42.7 (79)	185
U.S. manufacturing plants of parent company	1.66	15.2 (28)	34.8 (64)	49.5 (91)	183
Suppliers	1.61	9.7 (18)	41.9 (78)	48.4 (90)	186
Consultants	1.54	8.6 (16)	37.1 (69)	54.3 (101)	186

Note: Number of respondents in parentheses.
Source: Florida (1995).

Table 7
Sources of innovation by industry for sample laboratories

Source of new project ideas	Percent ranking very important			
	Electronics	Automotive	Chemical/materials	Biotechnology/drugs
In-house research staff	73.0	75.0	66.7	77.2
Customers	65.1	62.5	78.6	54.4
Other R&D laboratories	31.7	41.7	26.2	24.6
Competitors	36.5	41.7	16.7	24.6
Joint ventures	27.0	8.3	21.4	26.3
Universities	9.5	8.3	7.1	33.3
Corporate executives in home country	14.5	29.2	7.1	10.5
U.S. manufacturing plants of parent company	14.5	37.5	16.7	5.4
Suppliers	7.9	29.2	9.5	3.5
Consultants	7.9	12.5	7.1	8.8

Source: Florida (1995).

U.S. universities frequently (22%) or sometimes (26%).

As noted earlier, the literature on technical change notes that the sources of innovation differ substantially by industry and technical field, with some sectors drawing heavily from basic science and others linked quite closely to more applied activities (Rosenberg, 1982, Nelson, 1986, 1993, Rosenberg and Nelson, 1994). Nelson (1986) notes that the process of technological change is distinguished by a division of innovative labor wherein the relationships among innovating institutions (e.g. universities, R&D laboratories, and manufacturing plants) varies across technological fields. A study of industrial R&D laboratories (Levin et al., 1987, Klevorick et al., 1993), for example, found considerable variation in the role and importance of university research and academic science across industrial and technology fields.

There is considerable variation in the sources of new project ideas by industrial sector or technology, as Table 7 shows. On the one hand, respondents in the biotechnology sector were more than three times as likely to rate universities as a very important source of new project ideas. This may reflect the close connection between commercial biotechnology and advances in basic science, particularly university science, as noted above. Furthermore, nearly 9 in 10 foreign-affiliated biotechnology laboratories reported that they engage in cooperative research with U.S. universities, compared with an average of between half and two-thirds of laboratories in the three other sectors. On the other hand, respondents in the automotive sector were two to three times more likely to rate suppliers and manufacturing plants as very important sources of project ideas. These findings provide additional evidence of the heterogeneity of foreign R&D investment.

6. Management and organization

We now turn to the management and organization of foreign-affiliated R&D laboratories. We focus on two dimensions of the management and organization of sample laboratories: (1) external relationships between sample laboratories and other corporate units, and (2) the internal management and organization of sample laboratories. On the first dimension, studies of international R&D management note the difficulties associated with coordinating offshore R&D subsidiaries (see Bartlett and Ghoshal, 1989, Howells and Wood, 1993, Kenney and Florida, 1993, 1994). While offshore R&D subsidiaries require linkages to other corporate units and to the home base to coordinate their activities, complex reporting requirements and the perception of external control can have negative impacts on organizational performance. Furthermore, a number of studies highlight the tension between the autonomous pursuit of research and innovation and the need to channel and direct R&D activities toward areas of strategic interest (see Gomory, 1989, MIT Commission on Industrial Productivity, 1989, Florida and Kenney, 1990). Balancing

Table 8
Sources of research projects for sample laboratories

Source	Score	Often (%)	Sometimes (%)	Rarely (%)	Never (%)	N
In-house research scientists	3.59	68.1 (126)	23.8 (44)	7.0 (13)	1.1 (2)	185
In-house R&D managers	2.73	22.7 (42)	37.6 (70)	29.2 (54)	10.3 (19)	185
R&D managers at home	2.52	18.5 (32)	37.0 (64)	22.5 (39)	22.0 (38)	173
Corporate executives at home	2.42	15.7 (29)	29.2 (54)	36.2 (67)	18.9 (35)	185

Note: Number of respondents in parentheses.
Source: Florida (1995).

these objectives is a central element of the management of R&D subsidiaries.

6.1. Reporting requirements and external control

Offshore R&D facilities may report to related "sister" R&D facilities in the home country, to corporate headquarters, or to other units of the corporation. The survey collected data on the reporting requirements of sample laboratories with regard to sister R&D facilities and corporate headquarters. More than three-quarters (77.8%, $n = 144$) of respondents report to a sister R&D facility and nearly two-thirds (63.2%, $n = 117$) report to corporate headquarters. Furthermore, more than 40% of respondents indicated that they report to a sister R&D facility on a daily basis and 30% do so on a weekly basis. Roughly 35% of respondents indicated that they report to corporate headquarters on a daily basis and 30% do so weekly. The close links to and regular communication with sister R&D facilities also provide additional support for the conjecture that sample laboratories are adopting a technology-oriented posture to some degree.

There are numerous dimensions to reporting and external communication such as financial reporting, corporate coordination, general technical direction, and providing information on technological or market trends. These have different implications for the management of offshore R&D subsidiaries. There is considerable difference, for example, between providing regular financial reports (which does not compromise autonomy to any significant degree) and requiring external approval for new research projects (which reflects strong central control). The largest percentage of respondents (84.7%) reported coordination with other corporate activities as an important purpose of communication with the home base, followed by overall technical direction (78.0%), information on technical trends (73.7%), financial reporting (72.6%), and information on market trends (70.9%). Interestingly, new project ideas was cited by the lowest percentage of respondents as an important purpose of reporting and external communication (69.5%). [15]

The frequency with which R&D subsidiaries are required to obtain spending authorization from their corporate parents is another indicator of the level and extent of external corporate control. Respondents were asked to indicate how frequently their facility is required to obtain spending authorization from the parent company on a four-point scale where 1 is never and 4 is often. More than a third of respondents indicated that they were required to obtain spending authorization often and another third were required to do so sometimes. However, slightly more than 30% reported that they were rarely (19.8%) or never (11.6%) required to obtain spending authorization from the parent company.

[15] There is some variation in reporting by technology area. Foreign-affiliated R&D laboratories in the automotive sector were more likely to be linked both to sister R&D facilities and corporate headquarters. Nine in ten automotive laboratories were linked to sister R&D facilities compared with an average of 7 or 8 in 10 for the other sectors. More than 80% of automotive laboratories were linked to corporate headquarters compared with an average of 4 to 7 in 10 for the other three sectors.

The ability to initiate new projects and hire new scientific and technical staff are additional indicators of the autonomy of foreign R&D subsidiaries. Respondents were asked to indicate how frequently various groups initiate new research projects on a four-point scale where 1 is never and 4 is often (see Table 8). The findings indicate that sample laboratories possess considerable autonomy in initiating new projects and in hiring new scientific and technical staff. Survey respondents reported that in-house research scientists are the most frequent initiators of new research projects. Corporate executives and R&D managers in the home country were less frequently involved in initiating new projects. In fact, more than half of respondents reported that these two groups were rarely or never involved in initiating new projects. More than 90% of respondents reported that in-house research scientists have significant responsibility for new hiring decisions. Less than 40% of respondents reported that parent company managers have significant responsibility for new hiring decisions.

In short, the findings indicate that the foreign-affiliated R&D laboratories in our sample possess considerable autonomy in proposing projects, setting technical agendas, and hiring new staff with these functions being the primary responsibility of in-house scientific and technical staff. While sample R&D laboratories regularly report both to sister facilities and to corporate headquarters in the home country, such communication is principally concerned with administrative and coordination functions. While this communication does involve the overall technical direction of sample laboratories, it does not appear to impinge upon the design of new projects and the direct organization or on the performance of R&D activities.

7. Internal management and organization

The second dimension of the management and organization of foreign-affiliated laboratories involves the internal organizational structures and management practices of those facilities. We consider two aspects of such organizational and management practices: (1) the use of teams and other internal organizational practices, and (2) the degree to which foreign-affiliated laboratories seek to transfer the management practices associated with R&D laboratories of the parent company in the home country as opposed to emulating prevailing R&D management practices of the U.S. environment.

7.1. Internal management practices

Numerous studies note a shift in the nature of innovation management from individual work to team-based approaches (Clark and Fujimoto, 1991, Nonaka and Takeuchi, 1995). The literature further distinguishes between two types of teams: project teams composed of researchers, and cross-functional teams where representatives of manufacturing, marketing, research, and other corporate functions work together.

Respondents were asked to indicate how frequently scientists and engineers work in project teams, cross-functional teams, and on an individual basis on a four-point scale where 1 is never and 4 is often. A large percentage of respondents made use of each of these organizational approaches. Eight in ten respondents reported that they make frequent use of project teams, 58.6% reported frequent use of cross-functional teams, and 48.6% reported that researchers frequently work on an independent basis. The findings thus indicate that foreign-affiliated R&D facilities tend to mix management methods rather than relying exclusively on any one.

A number of studies highlight country-level differences in R&D management and organization (see for example Clark and Fujimoto, 1991). It is widely assumed that Japanese corporations lead in the use of team-based approaches to R&D management (Westney and Sakakibara, 1985, Nonaka and Takeuchi, 1995). In contrast to this view, Japanese-affiliated R&D laboratories in the United States are considerably less likely to make frequent use of either project teams or cross-functional teams than European affiliates. Research on the adoption of innovative management practices in manufacturing industries notes considerable variation in the adoption and use of teams by industrial sector (Florida and Jenkins, 1995). Overall, the biotechnology sector reported the highest shares of respondents which make frequent use of teams. Cross-functional teams were associated with the biomedical, pharmaceutical, and chemical fields, while project teams were associated with biomedical, audio-video equipment, pharmaceuticals, and telecommunications. The software industry was the least likely to make frequent use of teams, with more than a quarter of respondents (27.3%) reporting that they never use cross-functional teams.

7.2. *Transplant or emulate?*

The literature on multinational management notes that corporations at times seek to transfer certain manufacturing-management practices abroad. Studies of Japanese manufacturing in the United States provide evidence that Japanese automotive producers have successfully transferred key aspects of their work and production organization (see Kenney and Florida, 1993). There is interest among organizational researchers in the ability of multinational corporations to transplant and replicate aspects of their organizational and management systems to overseas locations. However, foreign-affiliated R&D laboratories may seek to fit into the immediate environment or to learn from and emulate existing U.S. approaches to managing innovation. Indeed, it is widely believed that the United States possesses a general climate which fosters creativity, and that U.S. organizations—both firms and universities—have developed management and organizational strategies which are conducive to and foster innovation.

The survey collected information on whether sample laboratories seek to transfer management systems and practices associated with parent company R&D laboratories in the home country, or conversely, whether they aim to emulate the innovation management systems of U.S. R&D laboratories, firms, and universities. The findings indicate that the foreign-affiliated R&D laboratories in our sample primarily seek to emulate and learn from prevailing U.S. organizational and management practices. Nearly 40% of respondents (39.5%, $n = 73$) reported that their management system is "American-style". More than half (52.4%, $n = 97$) of respondents reported their management system as "hybrid", combining elements of the management system used by their corporate parent and American-style innovation management. There is very little evidence in the survey data to support the notion that foreign-affiliated R&D laboratories aim to transfer and replicate the management practices of their corporate parent. Just 1.6% of respondents reported that they actively seek to replicate a research management system which is similar to that used by R&D facilities at home. There was little variation in this pattern either by technology field or country of ownership. The one exception, however, was the automotive sector. Respondents in this sector were considerably less likely than those in other sectors to adopt American-style innovation management and are considerably more likely to prefer hybrid approaches.

It useful to note that these findings stand in some contrast to the pattern in manufacturing to some degree, where studies note transfer and replication of home-country practices. This difference is as expected and should come as little surprise, given the underlying differences between manufacturing and R&D. Manufacturing is a highly standardized activity, while R&D is concerned, more or less by definition, with non-routine activities of the sort involved in knowledge generation (see Nonaka and Takeuchi, 1995). In this respect, foreign direct R&D investment in the U.S. appears at least in part to represent a strategy for learning about R&D management and organization as practiced in leading U.S. organizations. Research by Davis-Florida (1996a,b, 1997) is using these survey data and additional field research data to examine the factors that affect the organizational and management structures of foreign R&D laboratories. The preliminary findings from that work indicate that foreign-affiliated R&D laboratories adopt "American-like" characteristics and practices in order to compete effectively for high-quality scientific and technical talent.

8. Summary and conclusions

Foreign direct R&D investment has grown rapidly over the past decade and innovation has become increasingly global in nature. The United States is a particularly interesting case, since it is home to the largest concentration of foreign-affiliated R&D laboratories. This study has examined the scope, activities, and organization of foreign-affiliated R&D laboratories in the United States, leading to the following conclusions.

First, the findings of both the survey data and the regression analyses of R&D spending and the activities of sample laboratories highlight the importance of what can be termed a technology-oriented posture among foreign-affiliated R&D laboratories. This finding is particularly relevant given the emphasis on market factors (or demand-side factors) in the existing literature on FDI in R&D. The survey responses indicate that the three highest ranked R&D activities of sample laboratories reflect such a technology-oriented posture: developing new product ideas, obtaining information on scientific and technological developments in the United States, and obtaining access to high-quality scientists, engineers, and designers. Additional evidence of the importance of such a technology-oriented posture comes from the regression analyses of the relationship between R&D spending and the various activities of sample laboratories. The findings of these regressions indicate that technology-oriented factors—in particular gaining access to scientific and technical talent and developing links to the U.S. scientific and technical community—are the only factors that are significantly associated with R&D spending for the sample as a whole. The findings on innovative performance further indicate that sample laboratories are reasonably innovative, reinforcing the conjecture that foreign R&D investment increasingly reflects a technology-oriented posture as opposed to simply supporting offshore markets. The most important source of innovation or new project ideas for sample laboratories is in-house research staff; followed by customers, sister R&D facilities, competitors, and joint venture partners. Universities, manufacturing plants, and suppliers are rated as relatively unimportant sources of innovation by sample laboratories.

Second and related to this, the findings indicate that gaining access to human capital, specifically scientific and technical talent, is the central feature of the activities and objectives of the foreign-affiliated R&D laboratories in our sample. In other words, sample laboratories appear to focus substantial resources and effort on attracting high-quality scientific and technical talent, as opposed to monitoring technology, gaining access to science, customizing products, or supporting offshore markets. In fact, it can be argued that gaining access to high-quality scientific and technical human capital is relevant to each of those strategies. Taken together, these two findings illustrate the importance of supply-side factors in motivating foreign R&D investment. This suggests an important emendation to the literature on FDI in R&D. In our view, this literature has tended to overestimate the role and importance of demand-side factors (such as the size of local markets) in motivating FDIs in science and technology. Our results suggest that future studies should focus on the role of supply-side factors in motivating and shaping FDI in innovative activities.

Third, we find that foreign direct R&D investment is a heterogeneous process with some variation in activities and outputs across industrial sectors and technology fields. This is particularly true of the biotechnology industry where, for example, the assumption of a technology-oriented posture is more likely to be significantly associated with R&D spending. Foreign R&D laboratories in the biotechnology industry are also more likely to view universities as important sources of innovation than laboratories in other sectors. The notion of heterogeneity is in line with the literature on technical change which suggests that the nature of R&D—and of the innovation process more generally—tends to vary by industrial sector and field of technology. We believe there may be much gained from integrating this notion of industry differences, or what Nelson (1986) has referred to as the "division of innovative labor", into the theory of foreign direct R&D investment and from focusing explicitly on the role of industry differences in future studies of foreign investment in innovation.

Fourth, the management and organization of foreign R&D laboratories is a challenging undertaking, which essentially involves balancing corporate coordination and autonomy. Generally speaking, the foreign-affiliated R&D laboratories in our sample possess considerable autonomy in developing and managing their technical agendas, with in-house staff being principally responsible for initiating new projects and hiring new scientists and engineers. While foreign-affiliated laboratories regularly report to sister R&D facilities and to corporate headquarters in the home country, this communication is primarily concerned with administration and coordination and tends not to impinge upon in-house technical projects.

Fifth, we find that the foreign-affiliated R&D

laboratories in our sample make little apparent effort to transfer styles of management and organization associated with R&D laboratories in their home country. This stands in sharp contrast to the pattern in manufacturing, and may to some degree reflect underlying differences between manufacturing, a relatively standardized activity, and R&D which involves non-routine activities such as knowledge generation (see Nonaka, 1991, Nonaka and Takeuchi, 1995), a subject for which future research is clearly warranted.

Acknowledgements

Research funding was provided by grants from the Alfred P. Sloan Foundation, the Carnegie Bosch Institute, and the Japan Science and Technology Management Program. Special thanks are due to Joyce Davis-Florida who collaborated in all phases of this research and conducted the statistical analysis reported here. The Center for Survey Research at the University of Massachusetts–Boston administered the survey research. Michael Massagli oversaw the collection and initial analysis of the survey data. Lewis Branscomb and Harvey Brooks provided helpful comments.

References

Abernathy, W., Utterback, J., 1978. Patterns of innovation in technology. Technology Review 80 (7), 40–47.

Angel, D., Savage, L., 1994. Global localization? Japanese R&D laboratories in the USA. Clark University, Graduate School of Geography, Worcester, MA.

Archibugi, D., Michie, J., 1995. The globalization of technology: A new taxonomy, Cambridge Journal of Economics 19, 121–140.

Bartlett, C., Ghoshal, S., 1989. Managing Across Borders: The Transnational Solution. Harvard Business School Press, Boston, MA.

Blumenthal, D., Gluck, M., Louis, K.S., Wise, D., 1986a. Industrial support of university research in biotechnology. Science 231, 242–246.

Blumenthal, D., Gluck, M., Louis, K.S., Stoto, M., Wise, D., 1986b. University–industry research relationships in biotechnology: Implications for the university. Science 232, 1361–1366.

Cantwell, J., 1989. Technological Innovation and Multinational Corporations. Basil Blackwell, Oxford.

Casson, M. (Ed.), 1991. Global Research Strategy and International Competitiveness. Basil Blackwell, Oxford.

Clark, K., Fujimoto, T., 1991. Product Development Performance: Strategy, Organization, and Management in the World Auto Industry. Harvard Business School Press, Boston, MA.

Cohen, W., Florida, R., 1996. For Knowledge and Profit: University–industry Research Centers in the United States. Oxford University Press, New York.

Cohen, W., Florida, R., Goe, W.R., 1994. University–industry Research Centers in the United States. Carnegie Mellon University, Pittsburgh, PA.

Cohen, W., Nelson, R., Walsh, J., 1996. Appropriability conditions and why firms patent and why they do not in the American manufacturing sector. Mimeo, Carnegie Mellon University, Pittsburgh, PA.

Dalton, D., Serapio, M., 1993. U.S. research facilities of foreign companies. U.S. Department of Commerce, Technology Administration, Japan Technology Program, Washington, DC.

Dalton, D., Serapio, M., 1995. Globalizing industrial research and development. U.S. Department of Commerce, Office of Technology Policy, Asia–Pacific Technology Program, Washington, DC.

Davis-Florida, J., 1997, Strategies of intellectual capital development: The role of autonomy in foreign R&D laboratories in the United States, Department of Sociology, Harvard University, Cambridge, MA.

Davis-Florida, J., 1996a. International R&D laboratories in the U.S.: A case of strategic emulation. Harvard University, Department of Sociology.

Davis-Florida, J., 1996b. Scientific norms, reputational labor markets, and organizational structures: Organizational factors and the recruitment of Ph.D.s by foreign-affiliated laboratories in the U.S. Harvard University, Department of Sociology.

Dunning, J., Narula, R., 1995. The R&D activities of foreign firms in the United States. Unpublished paper.

Florida, R., 1995. Survey of foreign-affilated R&D laboratories in the United States. Center for Economic Development. Carnegie Mellon University, Pittsburgh, PA.

Florida, R., Jenkins, D., 1995. Why industry matters to organizational innovation. Carnegie Mellon University, Pittsburgh, PA.

Florida, R., Kenney, M., 1994. The globalization of innovation: The economic geography of Japanese R&D in the U.S. Economic Geography (October).

Florida, R., Kenney, M., 1990, The breakthrough illusion: Corporate America's failure to move from innovation to mass production, Basic Books, New York.

Gomory, R., 1989. From the ladder of science to the product development cycle. Harvard Business Review (November–December) 99–105.

Graham, E., 1992. Japanese control of R&D activities in the United States: Is there cause for concern. In: Arrison, T., Bergsten, C.F. (Eds.), Japan's Growing Technological Capabillty: Implications for the U.S. Economy. National Academy Press, Washington, DC, pp. 191–206.

Herbert, E., 1989. Japanese R&D in the United States, Research Technology Management (November–December) 11–20.

Howells, J., 1990. The internationalization of R&D and the development of global research networks. Research Policy 20, 472–476.

Howells, J., Wood, M., 1993. The Globalization of Production and Technology. Belhaven Press, London.

Kenney, M., 1986. Biotechnology: The University–industrial Complex. Yale University Press, New Haven, CT.

Kenney, M., Florida, R., 1993. Beyond Mass Production: The Japanese System and its Transfer to the U.S. Oxford University Press, New York.

Kenney, M., 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.

Klevorick, A., Levin, R., Nelson, R., Winter, S., 1993. On the sources and significance of interindustry differences in technological opportunities. Unpublished paper.

Kummerle, W., 1997, Building effective R&D capabilities abroad, Harvard Business Review, March–April, 61–70.

Levin, R., Klevorick, A.K., Nelson, R., Winter, S., 1987. Appropriating the returns from industrial R&D. Brooking Papers on Economic Activity, 783–820.

Mansfield, E., Teece, D., Romeo, A., 1979. Overseas research and development by U.S.-based firms. Economica 46 (May), 187–196.

MIT Commission on Industrial Productivity, 1989. Made in America. MIT Press, Cambridge, MA.

Mowery, D., Teece, D., 1992. The changing place of Japan in the global scientific and technological enterprise. In: Arrison, T., Bergsten, C.F. (Eds.), Japan's Growing Technological Capabillty: Implications for the U.S. Economy. National Academy Press, Washington, DC, pp. 108–143.

Mowery, D., 1997, Technological innovation in a multipolar system: Analysis and implications for US policy, prepared for the Council on Foreign Relations Study Group on the Globalization of Industrial R&D, New York.

Mowery, D., Teece, D., 1993. Japan's growing capabilities in industrial technology: Implications for U.S. managers and policymakers. California Management Review (Winter) 9–33.

National Science Board, 1993, Science and Engineering Indicators (National Science Board, Washington, DC).

Nelson, R., 1986. Institutions supporting technical advance in industry. American Economic Association Papers and Proceedings 76 (2), 186–189.

Nelson, R., 1993. National Systems of Innovation. Oxford University Press, New York.

Nonaka, I., 1991. The knowledge creating company. Harvard Business Review (November–December) 69–104.

Nonaka, I., Takeuchi, H., 1995. The Knowledge-creating Company. Oxford University Press, New York.

Patel, P., 1995, Localized production of technology for global markets, Cambridge Journal of Economics 19, 141–153.

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

Pearce, R., 1989. The Internationalization of Research and Development by Multinational Enterprises. St. Martin's Press, New York.

Porter, M. (Ed.), 1986. Competition in Global Industries. Harvard Business School Press, Boston, MA.

Porter, M., 1990. The Competitive Advantage of Nations. Free Press, New York.

Randazzese, L., 1996. Profit and the academic ethos: The activity and performance of university–industry research centers in the United States. Ph.D. dissertation, Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, PA.

Reid, P., Schriesheim, A. (Eds.) 1996, Foreign Participation in U.S. Research and Development: Asset or Liability?. (National Academy Press, Washington, DC).

Roberts, E., 1994. Strategic benchmarking of technology. Sloan School Working Paper, MIT, Cambridge, MA.

Ronstadt, R., 1977. Research and Development Abroad by U.S. Multinationals. Praeger, New York.

Ronstadt, R., 1978. International R&D establishment and the evolution of research and development abroad by seven U.S. multinationals. Journal of International Business Studies (Spring–Summer) 7–23.

Rosenberg, N., 1982. Inside the Black Box. Cambridge University Press, New York, pp. 141–159.

Rosenberg, N., Nelson, R., 1994. American universities and technical advance in industry. Research Policy 23, 323–348.

Utterback, J., 1989. Innovation and industrial evolution in manufacturing industries. In: Guile, B., Brooks, H. (Eds.), Technology and global industry. National Academy Press, Washington, DC, pp. 16–48.

Vernon, R., 1966. International investment and international trade in the product cycle. Quarterly Journal of Economics 80, 190–207.

Vernon, R., 1977. Storm Over the Multinationals. Basic Books, New York.

Von Hippel, E., 1988. The Sources of Innovation. Oxford University Press, New York.

Westney, D.E., 1992. Cross-Pacific internationalization of R&D by U.S. and Japanese firms. R&D Management 23, 3.

Westney, D.E., Sakakibara, K., 1985. Comparative study of the training, careers, and organization of engineers in the computer industry in Japan and the United States. MIT–Japan Science and Technology Program.

Wortman, M., 1990. Multinationals and the internationalization of R&D: New developments in German companies. Research Policy 19, 175–183.