

Foreign Direct R&D Investment in the United States

January 1996

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Acknowledgements: Research funding was provided by grants from the Alfred P. Sloan Foundation, Carnegie Bosch Institute, and Japan Science and Technology Management Program. 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.

Florida was a visiting professor in the Science, Technology and Public Policy Program at Harvard University's Kennedy School of Government in 1995-1996.

INTRODUCTION

Foreign direct investment in research and development has increased substantially over the past decade. Foreign corporations spent nearly \$15 billion on research and development (R&D) in the United States in 1994, accounting for more than 15 percent of total U.S. industrial R&D expenditures.

A number of studies have examined foreign direct R&D investment (Mansfield, Teece and Romeo 1979; Ronstadt 1977, 1978; Howells 1990; Cantwell 1989; Casson 1991; Westney 1992; Mowery and Teece 1992, 1993; 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 follow and support 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 take advantage of external scientific and technological capabilities and generate new technological assets (see Dunning and Narula 1995).

Despite the rapid growth of foreign direct R&D investment, little is known about the actual activities, organization, and performance of foreign R&D in the United States. 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 Dalton and Serapio 1993, 1995; Herbert 1990; Florida and Kenney 1994; Angel and Savage 1994). 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 paper examines the scope, activities, and performance of foreign-affiliated R&D laboratories in the United States, reporting the findings of a national survey. The survey identified more than 200 foreign-affiliated R&D laboratories, and achieved a response rate of 90 percent .

This paper seeks to make four key contributions. First, it distinguishes between two principal types of foreign direct R&D investment - market support and technology driven - and suggests that the latter is increasing in importance. The foreign direct investment literature emphasizes market support activities (Vernon 1966, 1977; Abernathy and Utterback 1978; Utterback 1989). Market support FDI essentially acts on the demand side and seeks to tailor products for foreign markets and provide technical support to off-shore manufacturing operations. Several studies note global localization strategies for manufacturing and product development multinational corporations (Porter 1986, 1990). Technology driven FDI acts on the Supply side and consists of two types: technology monitoring/acquisition and technology development. Several studies note that foreign R&D investment represents a strategy to maintain competitive advantage by generating new technological assets and capabilities (see particularly Dunning and Narula 1995; Cantwell 1989; Casson 1991; Howells and Wood 1993).

Second, foreign direct R&D investment is viewed as a heterogeneous phenomenon, with considerable variation in the nature and activities of foreign-affiliated R&D laboratories across fields of science and technology. While the foreign direct investment literature treats foreign direct investment 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 (Nelson 1986; 1993; Rosenberg 1982; Rosenberg and Nelson 1994).

Third, this paper submits that a key task of international R&D management involves balancing central corporate coordination with the autonomy required for innovation and creativity. Studies of international R&D management note the difficulties associated with coordinating off-shore 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 on innovative performance.

Fourth, foreign-affiliated R&D laboratories are seen to possess little incentive to transfer the management and organizational systems associated with R&D laboratories in their home country. 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 off-shore locations. This reflects underlying differences between manufacturing,

a relatively standardized activity, and R&D which involves non-routine activities such as knowledge generation (see Nonaka and Takeuchi 1995).

STUDY DESIGN

This study is based on a national survey of foreign-affiliated R&D laboratories in the United States. The sample was limited to 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 percent, including establishments that could not be located. Only 1 of the 361 contacted units refused to participate in the screening phase for an adjusted response rate of 99.7 percent, 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 percent (89.9 percent) 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 4 technology sectors (e.g. electronics, automotive technology chemicals and materials, and biotechnology and pharmaceuticals).(2)

SCOPE, MAGNITUDE AND ACTIVITIES

The key characteristics of foreign R&D affiliates in the U.S. are outlined in Table 1. Foreign-affiliated R&D laboratories ($n = 207$) spent \$5.14 billion on R&D in 1994.(3) This is equivalent to roughly 7 percent of U.S. company-financed industrial R&D (\$76.9 billion as of 1993, National Science Board 1993: 371), and more than a third (35.2 percent) of the of \$14.6 billion in total R&D by foreign corporations in the United States (Dalton and Serapio 1995: 7). (4) Foreign-affiliated R&D laboratories in the United States employed an estimated 65,800 workers, 25,000 scientists and engineers, and 7,400 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: 8).(5) The respondents averaged \$26.6 million in total R&D spending, and 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 researchers.

Foreign-affiliated R&D laboratories devoted \$396 million (8 percent) to basic research, \$1.8 billion (36 percent) to applied research, and \$3 billion (58 percent) to product development. Thus, foreign-affiliated R&D laboratories appear to be slightly more research intensive than U.S. industrial R&D as a whole which devoted 4.2 percent of total R&D effort to basic research, 23.5 percent to applied research, and 72.2 percent to product development in 1993 (National Science Board 1993: 33-336). This is not surprising since the U.S. figure includes the R&D resources of manufacturing plants and corporate administrative units, while the foreign-affiliated figure is limited to stand-alone R&D laboratories.

Table 1- Key Characteristics of Foreign-Affiliated R&D Laboratories

Number of Laboratories	207
R&D Spending (millions)	\$5,140
Basic Research (millions)	\$396
Applied Research (millions)	\$1,830
Product Development (millions)	\$2,976
Total Employment	65,800
Scientists and Engineers	25,000
Doctoral Level Researchers	7,400

Source: Richard Florida, Survey of Foreign-Affiliated R&D Laboratories in the United States, (Center for Economic Development, Carnegie Mellon University, 1995).

A handful of technologically advanced nations account for the overwhelming bulk of foreign R&D spending in the United States (Dalton and Serapio 1995: 11-12). More than half of respondents (53.8 percent, n = 100) had European parents, while 45.2 percent (n = 84) were affiliated with Asian parents. The only respondents outside these two regions were 2 Canadian affiliates. R&D laboratories affiliated with European parent companies accounted for more than three-quarters of R&D spending and two-thirds of employees.⁽⁶⁾ R&D 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). Foreign-affiliated R&D laboratories are concentrated in four broad fields of science and technology (biotechnology and pharmaceuticals, chemicals and materials, electronics, and automotive technology) and 13 sub-fields. The biotechnology and pharmaceutical sector is the largest of the four broad fields, with more than 60 percent 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), tele-communications (\$420 million),

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

Table 2 - R&D Spending and Employment by Technology

Technology	Number	R&D Spending (Millions of dollars)	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	
Computer & Peripherals		8	74 2,378 187,875	
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	
Chemicals/Materials	42	\$407	11,092 60,077	
Chemicals	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	

N-186

Source: Richard Florida, Survey of Foreign-Affiliated R&D Laboratories in the United States, (Center for Economic Development, Carnegie Mellon University, 1995).

TYPES OF FOREIGN DIRECT R&D INVESTMENT

There are two principal types of foreign direct investment in R&D: market support and technology driven. 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: listeningpost whose primary function is to monitor the scientific and technical capabilities of U.S. firms and universities and generating station which generate new scientific and technical knowledge. Some, however, continue to argue that off-shore R&D investment accounts for a small share of total industrial innovation and that multinational corporations tend to retain advanced research and development capabilities in the home country (see Porter 1986, 1990; Patel and Pavitt 1991).

As noted earlier, although the foreign direct investment literature treats foreign direct investment 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 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 Dalton and Serapio 1993, 1995; Herbert 1990; Florida and Kenney 1994; Angel and Savage 1994). Although they are based on either highly aggregate data or on case studies, these studies provide some evidence to suggest that investment motivations for foreign R&D investment differ by technology.

Respondents were asked to rate the importance of various activities on a 3 point scale where 1 is not important and 3 is very important (see Table 3). Generally speaking, the findings indicate that both technology driven and market support activities are important, but, that technology driven activities are on balance more important.

Table 3 - R&D Activities

Activity

Score

Very Important

Somewhat Important

Not Important

N=186

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
Access to
Scientific and Technical Talent
2.69

73.7
(137)

22.0
(41)

4.3
(8)

186
Customize
Products for
U.S
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.

N=186

Source Richard Florida, Survey of Foreign-Affiliated R&D Laboratories in the United States, (Center for Economic Development, Carnegie Mellon University, 1995).

The three highest ranked activities revolve around technology development. The respondents rated "developing new product ideas" as the highest ranked activity (2.84 score, 86.8 percent 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 percent 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 percent very important). In addition, very small percentages of respondents (less than 5 percent) rated any of these three activities as not important.

Two technology driven 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 percent of respondents listed the latter as somewhat important. These results suggest that foreign-affiliated R&D 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 support activities were somewhat less important to the overall activities of foreign-affiliated R&D laboratories. "Customizing products for the U.S. market" ranked fourth (2.56 score, 67.6 percent very important). In addition, nearly 12 percent of respondents listed 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 off-shore R&D and manufacturing in accordance with a global localization strategy.

As noted earlier, 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. The importance of R&D activities across the four technology sectors is summarized in Table 4. While developing new product ideas is clearly important to all sectors, a number of interesting patterns emerge for other activities. First, survey respondents in the biotechnology and pharmaceuticals sector rated technology driven activities, including developing new science and technology, obtaining information on U.S. science and technology, and establishing links to the U.S. science and technology communities, considerably higher than the other sectors. -This is not surprising given the close dependence of commercial biotechnology on advances in basic science, particularly university science (Blumenthal et al 1986a, 1986b; Kenney 1986; Levin et al 1987; Kievorick et al 1993).

Table 4 - R&D Activities by Technology Sector
(percent ratings very important)

Activity

Biotech-
nology /Drugs

Chemical & Materials

Electronics

Automotive

All Sectors
Developing
New Project
Ideas

87.7%

85.7%

83.5%

83.3%
86.6%

Obtaining
Information on Scientific and Technical
Developments
84.2

73.8

60.3

66.7

71.5
Access to
Scientific and Technical
Talent
75.4

76.2

74.6

62.5

73.7
Customize
Products for
U.S. Markets
57.9

81.0

62.9

79.2

67.6
Establish
Links to U.S.
Scientific and
Technical
Community
66.7

42.9

50.8

45.8

53.2

Work with Manufacturing
Facilities in
the U.S.

62.5

75.0

40.0

75.0

51.4
Developing
New Science
and
Technology

54.4

38.1

42.9

33.3

44.1

Source: Richard Florida, Survey of Foreign-Affiliated R&D Laboratories in the United States, (Center for Economic Development, Carnegie Mellon University, 1995).

Second, the automotive and chemical and materials sectors placed considerably more importance on market support activities, such as supporting U.S. manufacturing operations and customizing products for the U.S. market. There are two reasons for this. First, these sectors are characterized by a relatively high level of foreign manufacturing investment. More than 90 percent of the respondents in these two sectors report that their parent company has manufacturing facilities in the United States. Second, and related to this, these sectors also tend to have large consumer markets in the United States.

These patterns are reinforced by the findings for the 13 specific technology fields. On the one hand, a majority of respondents in the high-technology industries of pharmaceuticals (71.4 percent), software (63.6 percent), instruments (66.7 percent), and biotechnology (56.7 percent) ranked developing new science and technology as very important. On the other hand, large shares of respondents in audio-video equipment (88.9 percent) telecommunications (85.7 percent), and automotive technology (83.3 percent) 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. These findings reinforce the point that market support activities are associated with industries with high levels of foreign manufacturing investment and large consumer markets.

The findings here shed light on two interrelated aspects of the process of foreign direct R&D investment. First, they indicate the importance of technology activities. Foreign direct R&D investment in the United States is significantly oriented to developing new products, obtaining information on U.S. science and technology, and gaining access to scientific and technical talent. Second, and related to this, there is considerable heterogeneity in the activities and investment motivations of foreign-affiliated R&D laboratories. Simply put, high-technology and science-intensive sectors - particularly biotechnology - tend to emphasize technology development, while sectors with high levels of manufacturing investment and large consumer markets emphasize market support. This suggests that the process of foreign direct R&D investment is considerably more heterogeneous than the foreign direct investment literature suggests, though it is in line with the technical change literature which emphasizes industry- and technology-level differences.

Innovative Output and Performance

The technology development activities of foreign direct R&D investment can be probed more directly by exploring innovative outputs. Economists and other experts note 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, Florida and Goe 1994). 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. Still, there are a number of useful measures of the more direct and tangible outputs of the innovation process, such as patents and published articles, which can be measured. The survey collected data on four such classes of direct innovation outputs: patent applications, patents, copyrights, and articles published in the open scientific and technical literature.(7)

The findings indicate that foreign-affiliated laboratories in the United States are reasonably innovative, producing 2,469 patent applications, 1,068 patents, 669 copyrights, and 1,812 published articles in 1994. The 1,068 patents reported by foreign-affiliated R&D laboratories in the United States is but a small fraction of the more than 30,000 U.S. patents granted to foreign corporations (National

Science Board 1993). It is important, 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.(8) When this is done, foreign-affiliated R&D laboratories appear to be slightly more innovative than U.S. industrial R&D. Foreign-affiliated R&D laboratories in the United States generated 7.3 patents per \$10 million in R&D spending compared to 4.7 patents per \$10 million of company-financed industrial R&D for the U.S. as a whole.(9) Foreign-affiliated R&D laboratories produced 12.8 patents per 100 scientists and engineers - more than double the rate of 4.9 patents per 100 scientists and engineers for U.S. industrial R&D.(10)

The production of scientific and technical articles is an indicator of the generation of new scientific and technical knowledge. Foreign-affiliated laboratories produced an average of 16 articles in the open scientific literature per \$10 million in R&D expenditures. This is nearly ten times the rate of 1.65 articles per \$10 million of company-financed industrial R&D for the U.S. as a whole.(11) 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 employees, 25.7 articles per 100 scientists and engineers, and 95.5 articles per 100 doctoral-level researchers, nearly 1 article per doctoral-level researcher per year. The rate of 10.1 articles per 100 scientists and engineers for foreign-affiliated R&D laboratories is significantly higher than the rate of 1.65 articles per 100 scientists and engineers for U.S. industrial R&D.(12) This is understandable, however, given that the U.S. industrial total is not limited to scientists and engineers working in R&D laboratories but includes those working in manufacturing units and other corporate activities as well as those working in R&D laboratories.

The technical change literature would expect considerable differences in innovative performance by technology, and this is indeed the case both in terms of the production of patents and published articles. The survey data on innovative performance by technology field are summarized in Table 5. Chemicals ranked first in patent performance (14.2 patents per \$10 million in R&D spending) followed by instruments (10.5 patents), computer software (10.1 patents), audio-video equipment (7.8 patents), automotive manufacturing (7.6 patents), semiconductors (6.2 patents), and biotechnology (6.2 patents). Many of the same fields led in patent performance per employee, although their order was somewhat changed.

Materials led in the production of published articles with 45.6 articles per \$10 million in R&D spending, followed by instruments (38.8 articles), pharmaceuticals (30.5 articles), computer software (23.6 articles), biotechnology (19.7 articles), and semiconductors (18.6 articles). There was some change in these rankings in terms of articles produced per 100 scientists and engineers with computer software leading (63.3 articles), followed by biotechnology (38.7 articles), pharmaceuticals (33.8 articles), materials (33.4 articles), and semiconductors (26.6 articles). (13)

Table 5 -Innovative Performance

Technology

Patents per \$10
Million
R&D Spending
(N=149)

Patents per 100 Employees
(N=165)

Articles per \$10 million
R&D Spending (N = 155)

Articles per 100 Scientists
& Engineers

(N = 172)

Biotechnology/Drugs

4.71

2.45

19.89

32.33

Biotechnology

6.19

3.04

19.65

38.70

Pharmaceuticals

2.17

2.27

30.49

33.82

Biomedical

2.92

1.28

10.86

16.74

Chemical/Materials

12.43

4.15

14.46

20.30

Chemicals

14.16

4.77

9.90

18.44

Materials

1.33

0.10

45.58

33.39

Automotive

5.98

5.34

9.65

19.39

Manufacturing

7.60

6.64

12.44

24.83

Design

0.00

0.00

2.40

2.00

Electronics

6.36

5.53

15.77

25.59

Computers and
Peripherals

4.74

6.78

7.22

21.59

Computer Software

10.06

4.60

23.55

63.27

Audio-Video

7.77

6.85

10.96

11.35

Semiconductors

6.22

7.89

18.61

26.56

Telecommunications

3.22

3.33

5.89

10.53
Instruments

10.54

3.15

38.79

16.67
All Fields

7.32

4.18

16.02

25.72
Y

Source: Richard Florida, Survey of Foreign-Affiliated R&D Laboratories in the United States, (Center for Economic Development, Carnegie Mellon University, 1995)

The findings here indicate that foreign-affiliated R&D laboratories in the United States produce a reasonable rate of innovative output. In fact, innovative outputs are produced even in fields such as automotive technology, audio-video equipment, and chemicals which tend to emphasize market support. These findings thus support the conjecture that foreign-affiliated R&D laboratories emphasize technology development activities at least to some degree. Furthermore, the variation in innovative output by technology further reinforces the notion of heterogeneity in foreign direct R&D investment.

SOURCES OF INNOVATION

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. Von Hippel (1988) notes the importance of customers and end-users as sources of innovation. Recent 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 partners, suppliers, and universities) grows (see Roberts 1994). To shed light on this issue, the survey collected detailed data on the sources of innovation for foreign-affiliated R&D laboratories, including: in-house research staff, corporate executives, manufacturing plants, customers, suppliers, universities, joint Joint venture partners, competitors, and consultants. Respondents were asked to rate the importance of each as a source of new project ideas on a 3 point scale where 1 is not important and 3 is very important. The sources of innovation for foreign-affiliated laboratories are presented in Table 6.

The leading source of project ideas is in-house research staff (score = 2.72), 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.

Table 6 - Sources of Innovation

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)

Rosenberg 1982; 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; Kievorick et al. 1993), for example, found considerable variation in the role and importance of university research and academic science across a large number of technology fields. There is considerable variation in the sources of new project ideas by technology field 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 reflects 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 to 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 thus provide additional evidence of the heterogeneity of foreign R&D investment.

Table 7 - Sources of Innovation by Technology
(percent ranking very important)

Source of New Project Ideas	Biotechnology		Electronics		Automotive		Chemical/ Materials	
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	33.5				
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: Richard Florida, Survey of Foreign-Affiliated R&D Laboratories in the United States, (Center for Economic Development, Carnegie Mellon University, 1995).

MANAGEMENT AND ORGANIZATION

Studies of international R&D management document the difficulties associated with coordinating off-shore R&D subsidiaries (see Bartlett and Ghoshal 1989; Howells and Wood 1993; Kenney and Florida 1993; Florida and Kenney 1994). Off-shore 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. Reporting requirements also reflect the nature of R&D activities to some degree. Reporting to sister R&D facilities tends to reflect technology activities, while reporting to corporate headquarters or to manufacturing units is more likely to concern manufacturing support. While foreign 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 MIT Commission on Industrial Productivity 1989; Florida and Kenney 1990). Balancing these objectives is a central element of the management of R&D subsidiaries.

Reporting Requirements and External Control

The survey explored the reporting requirements of foreign-affiliated R&D laboratories with regard to sister R&D facilities and corporate headquarters. More than three-quarters (77.8 percent, n = 144) of respondents report to a sister R&D facility and nearly two-thirds (63.2 percent, n = 117) report to a corporate headquarters. Furthermore, more than 40 percent of respondents indicated that they report to a sister R&D facility on a daily basis and 30 percent do so on a weekly basis. Roughly 35 percent of respondents indicated that they report to corporate headquarters on a daily basis and 30 percent do so weekly. Close links to and regular communication with sister R&D facilities provide additional indication of the technology driven nature of foreign R&D investment in the United States.

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 off-shore R&D subsidiaries. There is considerable difference, for example, between providing regular financial reports and requiring external approval for new research projects. The largest percentage of respondents (84.7 percent) reported coordination with other corporate activities as an important purpose of communication with the home base, followed by overall technical direction (78.0 percent), information on technical trends (73.7 percent), financial reporting (72.6 percent), and information on market trends (70.9 percent). Interestingly, new project ideas was cited by the lowest percentage of respondents as an important purpose of reporting and external communication (69.5 percent).(14)

The frequency with which R&D subsidiaries are required to obtain spending authorization from their corporate parents is an 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 1 to 4 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 sometime. However, slightly more than 30 percent reported that they were rarely (19.8 percent) or never (11.6 percent) required to obtain spending authorization from the parent company.

The ability to initiate new projects and hire new scientific and technical staff are indicators of the autonomy of foreign R&D subsidiaries. Respondents were asked to indicate how frequently various groups initiate new research projects on a 1 to 4 point scale where 1 is never and 4 is often (see Table 8). The findings indicate

that foreign- affiliated R&D 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 percent of respondents reported that in-house research scientists have significant responsibility for new hiring decisions. Less than 40 percent of respondents reported that parent company managers have significant responsibility for new hiring decisions.

Table 8 - Sources of Research Projects

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 Richard Florida, Survey of Foreign-Affiliated R&D Laboratories in the United States, Center for Economic Development, Carnegie Mellon University, 1995).

In short, the findings indicate that foreign-affiliated R&D laboratories possess considerable autonomy in proposing projects, setting technical agendas, and hiring new staff with these functions being the primary responsibility of in-house technical staff. While foreign-affiliated 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 foreign R&D laboratories, it does not appear to impinge upon the design of new projects and the direct organization nor on the performance of research and development activities.

Use of Teams

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 1 to 4 point scale where 1 is never and 4 is often. A large percentage of respondents made use of each of these organizational approaches as Table 9 shows. Eight in ten respondents reported that they make frequent use of project teams, 58.6 percent reported frequent use of cross-functional teams, and 48.6 percent 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.

Table 9 - Use of Teams

	Score	Often	Sometimes	Rarely	Never	N=
Project Teams	3.79	81.6%				
(152)	16.1%					
(30)	1.6%					
(3)	0.5%					
(1)	186					
Cross-Functional Teams	3.47	58.6				
(109)	33.9					
(63)	3.2					
(6)	4.3					
(8)	186					
Individual	3.41	48.6				
(90)	23.2					
(42)	19.5					
(36)	8.6					
(36)	185					

Note: Number of respondents in parentheses.

Source Richard Florida, Survey of Foreign-Affiliated R&D Laboratories in the United States, (Center for Economic Development, Carnegie Mellon University, 1995).

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; Aoki and Rosenberg 1991; 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 percent) reporting that they never use cross-functional teams.

Transplants versus Americanization

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 of the ability of Japanese automotive producers to transplant key aspects of their work and production organization (see Kenney and Florida 1993.) There is interest among organizational researches in the ability of multinational corporation to transplant and replicate aspects of their organizational 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 foster creativity, and that U.S. organizations - both firms and universities - have developed management and organizational strategies which facilitate innovation.

The survey collected information on whether foreign-affiliated R&D 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 indicated that foreign-affiliated R&D laboratories primarily seek to emulate and learn from prevailing U.S. practices. Nearly 40 percent of respondents (39.5 percent, n = 73) reported that their management system is "American-style." More than half (52.4 percent, 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 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 percent 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 is little variation in this pattern either by technology field or country of ownership. The one exception, however, is the automotive sector.

Respondents in this sector are considerably less likely than those in other sectors to adopt American-style innovation management and are considerably more likely to prefer hybrid approaches.

SUMMARY AND CONCLUSIONS

Foreign direct R&D investment has grown rapidly over the past decade. The United States has attracted a large amount of foreign R&D spending and a considerable number of R&D laboratories affiliated with foreign companies. This study has examined the scope, nature, activities, and performance of foreign-affiliated laboratories in the United States, leading to the following conclusions.

First, foreign direct R&D investment involves technology development as well as market support, with technology development being on balance more important. This stands in some contrast to the extant literature which places emphasis on market support. The three highest ranked R&D activities of foreign-affiliated laboratories revolve around technology development: 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. The leading market support activity - customizing products for the U.S. market - ranked fourth.

The findings further indicate that foreign-affiliated R&D laboratories are reasonably innovative, exhibiting rates of patenting and article production which exceed those of U.S. industrial R&D. This reinforces the conjecture that foreign R&D investment increasingly reflects technology development as opposed to more traditional market support. The most important source of innovation for foreign-affiliated R&D laboratories is their own in-house research staff. Customers are second, followed by sister R&D facilities, competitors, and joint venture partners. Universities, manufacturing plants, and suppliers are rated as relatively unimportant sources of innovation for foreign-affiliated R&D laboratories. Second, foreign direct R&D investment is a heterogeneous process. The R&D activities of foreign-affiliated laboratories vary considerably by technological field. Not surprisingly, technology development is associated with high-technology fields such as biotechnology and computer software, while market support is associated with industries which have high levels of foreign manufacturing investment and large U.S. consumer markets. There is also considerable variation in both innovative performance and the sources of innovation across technologies. Universities are considerably more important sources of innovation in the biotechnology industry, while manufacturing plants and suppliers are more important to the automotive sector. This 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 technology field. There is likely to be much gained from embedding the concept of a division of innovative labor from the technical change literature (Nelson 1986) into the theory of foreign direct R&D investment.

Third, management of foreign R&D subsidiaries essentially involves balancing corporate coordination and autonomy. Generally speaking, foreign-affiliated R&D laboratories 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 hiring new scientists and engineers. While foreign-affiliated laboratories regularly report to communication is primarily concerned with administration and coordination and tends not to impinge upon in-house technical projects.

Fourth, foreign-affiliated R&D laboratories make little apparent effort to transfer styles of management and organization associated with R&D laboratories in their home country. Nearly 40 percent of laboratories prefer "American-style" innovation management, and more than half characterized themselves as hybrids. Less than two percent of respondents seek to replicate the management style of R&D laboratories at home. This stands in 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 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.

ENDNOTES

- 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 research and development, particularly since the sample for this study and the Commerce Department list are drawn from largely the same sources.
- 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 5,875 doctoral-level researchers.

- 6) These data represent reported spending by respondents only and are not estimated to account for the total sample population.
- 7) 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.
- 8) The performance measures used here are modelled after those in Cohen, Florida and Gore (1994; also see, Cohen and Florida 1996; Randazzese 1996).
- 9) The U.S. average is based upon 36,074 patents and \$76.9 billion in company-financed R&D (National Science Board 1993: 455, 371).
- 10) 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: 455, 309).
- 11) The U.S. data are for 1991 - 12,660 articles, \$76.9 billion in company-financed industrial R&D (National Science Board 1993: 428, 371).
- 12) The U.S. figure is for 1989 - 11,963 papers, 726,000 scientists and engineers (National Science Board 1993: 428, 309).
- 13) There was also variation in innovative performance by country of ownership. R&D laboratories affiliated with French parents led in patent performance per R&D spending, while laboratories affiliated with Japanese parents led in patent performance per employee and in the production of scientific articles. Japanese affiliates produced nearly three times as many published articles (147.9 articles) per 100 doctoral-level researchers as European affiliates (58.2 articles per 100 doctoral-level researchers), (see Florida 1996)
- 14) 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 to an average of 7 or 8 in ten for the other sectors. More than eighty percent of automotive laboratories were linked to corporate headquarters compared to an average of 4 to 7 in ten for the other three sectors.

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