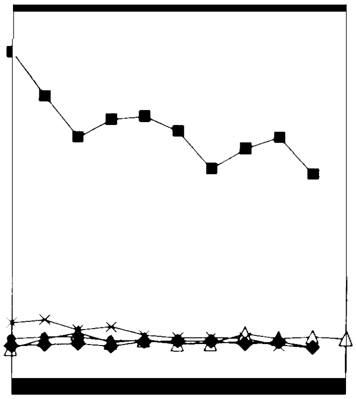
Multinationals and the Location of Innovation 4

Chapter 4 builds on numerous recent analyses that register concern about the comparative performance of the U.S. innovation system and the long-term health of the domestic technology base. OTA and others have analyzed the impact of the U.S. innovation system's orientation toward defense technologies on the nation's relative technological position and international competitiveness.[1] Other analyses have focused on the relative inability of U.S. firms to commercialize new technologies, and the dearth of policy efforts to encourage the diffusion of new technologies along with more tacit forms of knowledge.[2] Given the central role of multinational enterprises (MNEs) in the production and diffusion of new technology—and hence in the competitiveness of national economies—this chapter focuses on the relationship between MNEs and national innovation systems.

Many analysts have noted that MNEs in recent years have increased the cross-border transfer of technological knowledge and



[1] See U.S. Congress, Office of Technology Assessment, *Defense Conversion: Redirecting R&D*, OTA-ITE-552 (Washington, DC. U.S. Government Printing Office, May 1993); U.S. Congress, Office of Technology Assessment, *Competing Economies: America, Europe, and the Pacific Rim*, OTA-ITE- 498 (Washington, DC: U.S. Government Printing Office, October 199 1), National Science Board, *The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues* (Washington, DC: National Science Foundation, 1992).

[2] See J.A. Alic, "'Technical Knowlege and Technology Diffusion: New Issues for U.S. Government Policy," *Technology Analysis and Strategic Management* 5(4):369-383, 1993; U.S. Congress, Office of Technology Assessment, *Making Things Better: Competing in Manufacturing*, OTA-ITE-443 (Washington, DC: U.S. Government Printing Office, February 1990). OTA is conducting an assessment of difficulties U.S. industry has faced in the commercialization of new technologies.

assets, a process referred to as the globalization of technology.[3] However, globalization does not imply that national technology bases are becoming more integrated and interdependent. First, most of the core research and technology development activities of MNEs remain centralized in the home market. Second, much of the technology sold across borders stays within MNE networks. And third, cross-border technical alliances and other forms of interfirm collaboration are prominent in a limited number of sectors, although the available data are inadequate to assess the net significance of alliances as a channel for international technology diffusion.

OTA's analysis shows that, although technology has become increasingly global and will likely become more so in the future, technology development in the aggregate remains firmly rooted in national technology bases. Moreover, MNEs based in different countries and operating in different industrial sectors vary in their tendency to retain core technology development capabilities in the home market.

These conclusions follow from an analysis of three principal mechanisms through which MNEs can extend technology across national borders: first, through overseas R&D activities; second, through the direct sale of technology in the form of intellectual property, in exchange for royalties and license fees; and third, through cooperative R&D agreements or alliances between firms, as well as between firms and other R&D organizations such as universities.[4] If there are consistent national differences in the strategic technology activities of MNEs, then those differences should be reflected in each of these areas.

THE LOCATION OF RESEARCH AND DEVELOPMENT

Historically, R&D has been the last aspect of corporate activity to take on a global dimension, since the economies of scale associated with research activities tend to favor centralization. However, as firms establish foreign production capabilities, they often decentralize selective elements of their R&D. In addition to supporting local production facilities, firms will move R&D abroad for a variety of reasons:

- to acquire foreign technology;
- to customize products for local markets;
- to stay abreast of technological developments;
- to gain access to foreign R&D resources, such as universities, public and private laboratory facilities, and scientists and engineers;
- to assist the parent company in meeting foreign regulations and product standards; and
- to gain cost efficiencies.

Consequently, as production and commerce become increasingly international, R&D should likewise exhibit a more global character.

Analysts differ, however, on the extent and breadth of the globalization of R&D. Some studies conclude that technology has globalized so extensively that it is becoming difficult to identify technologies with individual firms or to distinguish one national technology base from another.[5] Others note that while R&D has indeed become

[3] See "Technology and Globalization," in Organisation for Economic Co-Operation and Development (OECD), *Technology and the Economy: The Key Relationships* (Paris, France: OECD, 1992), pp. 209-236. For an extended analysis with particular reference to MNEs, see O. Granstrand, L. Håkanson, and S. Sjölander, *Technology Management and International Business: Internationalization of R&D and Technology* (New York, NY: John Wiley, 1992).

[4] Two of these phenomenon—the increased frequency of both offshore R&D and international technical alliances-are associated with the rise of "technoglobalism" during the 1980s. See OECD, Economic Analysis and Statistics Division, *Performance of Foreign Affiliates in OECD Countries* (Paris, France: OECD, forthcoming), pre-publication copy p. 49.

[5] T.H. Lee and pp. Reid (eds.), *National Interests in an Age of Global Technology* (Washington, DC: National Academy Press, 1991), P. 72.

more mobile, MNEs move R&D abroad far more slowly than production, sourcing, marketing, and other business activities.[6] Others contend that firms are responding to global competition by watching R&D activities closely and striving to retain centralized control.[7] Still others agree that MNEs conduct relatively little R&D outside the home country, but note that the strategies and policies of MNEs can affect the way R&D is owned, organized, and located.[8] Finally, OECD analyses indicate that major MNEs may be expanding their core R&D activities across national borders. Some foreign acquisitions appear aimed at gaining access to technology and other R&D resources that are already established in particular markets (for instance, biotechnology in the United States). In the United States, Germany, and the United Kingdom, foreign firms "are spending substantial sums on R&D, mainly for local markets though increasing y for global ones, reflecting new strategies in R&D intensive industries."[9]

OTA's analysis indicates that R&D has become more global in character, as demonstrated by the overseas R&D activities of foreign affiliates. Nevertheless, relative to production and sourcing, R&D across the advanced industrial states remains highly centralized in the home market operations of MNEs. The degree of centralization, however, varies by country of origin as well as by sector. The patterns underlying this assessment can be seen in three areas of inquiry: the R&D activities of foreign affiliates in the United States; the R&D activities of U.S. affiliates in foreign markets; and the relationship between R&D conducted by affiliates and that conducted by MNE parents.

R&D by Foreign Affiliates in the United States

R&D spending by foreign affiliates in the United States has increased substantially, measured as a percentage of total R&D expenditures by U.S. businesses. In 1982 foreign affiliates accounted for 9.4 percent ($4.5 billion) of all business R&D spending in the United States; by 1992 that share had risen to 16.4 percent ($10.7 billion).[10] Although relatively small in absolute terms, the rate of increase in R&D spending by foreign affiliates has been much more rapid than that of total U.S. business R&D. Between 1982 and 1992, R&D expenditures by foreign affiliates in the United States grew by 138 percent (see figure 4-1), while total business R&D expenditures grew by 39 percent (from $48.6 to $67.0 billion in constant dollars).[11]

Affiliates from other advanced industrial nations increased their total R&D spending in the United States rapidly over the course of the 1980s and early 1990s (see figure 4-2). During that period U.K. and German affiliates consistently outspent French and Japanese affiliates. Adjusted for inflation, U.K. affiliates in the United States spent $1.8 billion on R&D in 1992, and German affili-

[6] J.A. Cantwell, *Technological Innovation and Multinational Corporations* (Oxford, UK: Basil Blackwell, 1989).

[7] P. Patel and K. Pavitt, "Large Firms in the Production of the World's Technology: An Important Case of 'Non-Globalization'" *Journal of International Business Studies* First Quarter: 1-21, 1991.

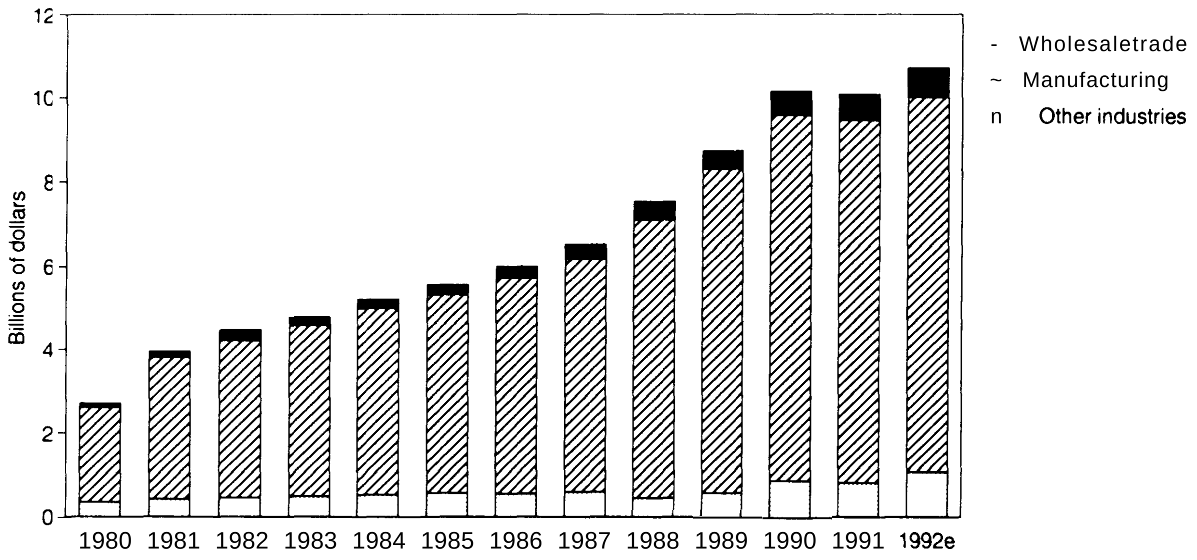
[8] J.H. Dunning, "Multinational Enterprises and the Globalization of Innovatory Capacity," *Research Policy* 23(1):67-88, Jan. 1994.

[9] G. Vickery, "Global Industries and National Policies," *OECD Observer 179:* 11-14, December 1992/January 1993. Smaller countries with limited domestic R&D resources (e.g. Sweden, Netherlands, Switzerland) tend to locate even more R&D abroad, often as a means of tapping foreign technological resources.

[10] In constant 1987 dollars. Data on R&D spending by foreign affiliates from U.S. Department of Commerce, *Foreign Direct Investment in the United States: An Update* (Washington, DC: US GPO, June 1993), table 56; and U.S. Department of Commerce, *Foreign Direct Investment in the United States: Preliminary 1992 Estimates* (forthcoming, 1994), table H-3A. Data on total U.S. business R&D are from National Science Board, *Science and Engineering Indicators—1993* (Washington, DC: U.S. GPO, 1993), NSB 93-1, appendix table 4-4, p. 333.

[11] National Science Board, *Science and Engineering Indicators—1993. Op cit.* footnote 10.

FIGURE 4-1: R&D Expenditures of Foreign Affiliates in the United States by Sector, 1980-1992 (constant 1987 dollars)



NOTE: 1992 data are preliminary.

SOURCE: OTA, based on data on U S Department of Commerce, Economics and Statistics Administration, *Foreign Direct Investment* in *the United States: An Update, Review and Analysls of Current Developments* (Washington, DC U.S. Government Printing Off Ice, June 1993), appendix C, table 56 (hereafter cited as ESA, *FDIUS), U S* Department of Commerce, Bureau of Economic Analysis, Foreign *Direct Investment* in *the United States Operations of U.S. Affiliates of Foreign Companies, 1987* Benchmark Survey, revised 1988-1991 estimates, and preliminary 1992 estimates (Washington, DC U S Government Printing Off Ice, 1990-1994), table H-1 (hereafter cited as BEA, *FDIUS)*

ates spent $1.6 billion. Japanese and French affiliates have spent comparatively less on R&D over time—$l.3 billion and $1.0 billion, respectively, in 1992. [12]

Since 1980,86 percent of the total R&D by foreign affiliates in the United States has been in manufacturing, increasing slightly from 82 percent in 1980 to 84 percent in 1992.’3 Canadian firms accounted for the largest share—19 percent—among foreign affiliates in the United States during 1992 (see figure **4-3).** German, U. K., and Swiss affiliates each accounted for $1.5 billion or 16 percent, compared to $1.0 billion or approximately 10 percent for French and Japanese affiliates.

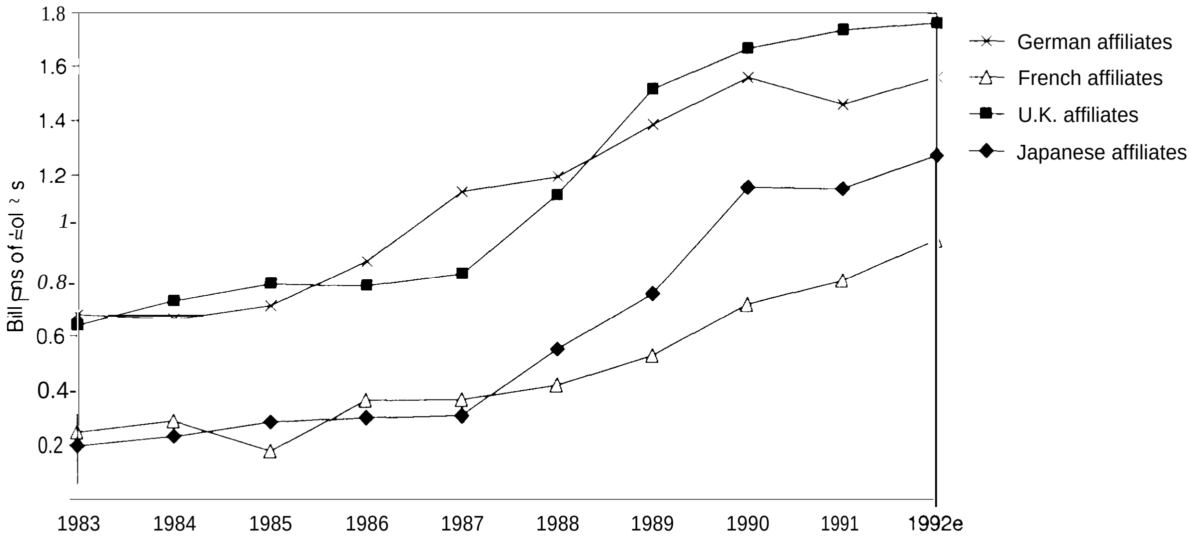
Between 1985 and 1992, over half of all R&D and 81 percent of the manufacturing R&D conducted by foreign affiliates in the United States was concentrated in three sectors: chemicals (28 percent); pharmaceuticals (23 percent); and electrical and nonelectrical machinery (29 percent combined). [14] The most rapid rate of growth has been in the pharmaceutical sector, where foreign

[12] In constant 1987 dollars. Data from U.S. Department of Commerce, Bureau of Economic Analysis, Survey *of Current Business* (Washington, DC: May 1993); table 1, p. 89; and U.S. Department of Commerce, Bureau of Economic Analysis, *Foreign Direct Investment in the United States: Preliminary 1992 Estimates* (Washington, DC: forthcoming, 1994); table H-3A.

[13] See figure 4-I.

[14] U.S. Department of Commerce, BEA, *Foreign Direct Investment in the United States: Preliminary 1992 Estimates,* op cit. footnote 12.

FIGURE 4-2: Gross R&D Expenditures of Foreign Affiliates in the United States by Nationality of Ownership, 1983-1992 (constant 1987 dollars)



NOTE: 1992 data are preliminary.

SOURCE: OTA based on data in BEA, *FDIUS,* tables 8 and H-6 (1 983-1986) and tables A-6 and H-2 (1 987-1992)

affiliates increased their R&D spending from $596 million in 1985 to $2.8 billion in 1992 (in constant dollars), an average increase of 26 percent per year. R&D spending by foreign affiliates also has grown rapidly in industrial chemicals and machinery, again with the most rapid rates of growth taking place in the late 1980s (see figure 4-4).

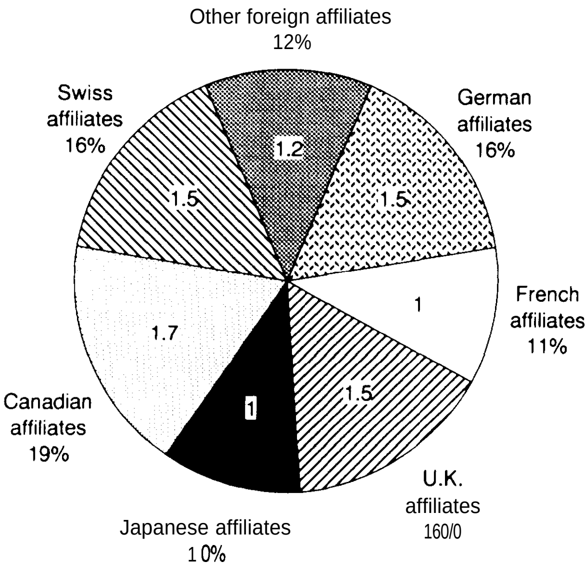
The R&D spending increases shown in figure 4-2 correspond to a very active period of merger and acquisition activity by foreign investors. The value of foreign acquisitions in the United States jumped from $31.5 billion in 1986 to $64.9 billion in 1988, and remained quite high during 1988-90.[15] The correspondence between this period of high acquisition activity and the rise in R&D spending by foreign affiliates after 1986 implies that much of the increase in affiliate R&D was due to acquisitions of U.S. research facilities, as opposed to the transfer of R&D activities from the home market to existing affiliates in the United States.[16] With only a few notable exceptions, such as NEC's laboratory in Princeton, most industrial laboratories run by foreign affiliates in the United States have been established not through new investment dedicated to R&D activities per se but rather through the merger and acquisition strategies of foreign firms.[17]

[15] See figure 5-8 in chapter 5.

[16] For supporting analyses, see OECD, *Performance of Foreign Affiliates,* op. cit., footnote 4, p. 50; U.S. Department of Commerce, BEA, *Foreign Direct Investment in the United States: An Update,* op. cit., footnote 10, p. 70; and H. Fusfeld, *Industry's Future: Changing Patterns of Industrial Research* (unpublished manuscript, 1994).

[17] H. Fusfeld, op. cit. footnote 16.

FIGURE 4-3: Manufacturing R&D Expenditures of Foreign Affiliates in the United States by Nationality of Ownership, 1992



NOTE: Brackets show R&D expenditures in constant 1987 dollars, total expenditures for manufacturing R&D by foreign affiliates = $95 billion

SOURCE: OTA, based on data in BEA, *FDIUS,* preliminary 1992 estimates, table H-4

Variations in investment strategies affect the average R&D intensity of foreign affiliates in the United States.[18] Figure 4-5 shows that the R&D intensity for European affiliates is above the average for all affiliates, which reflects the relatively high percentage of European foreign direct investment in the United States (FDIUS) that is directed to manufacturing. German affiliates in the United States consistently have had the highest R&D intensity, which reflects the concentration of German affiliates in R&D-intensive manufacturing industries, such as chemicals and pharmaceuticals.[19] Similarly, the comparatively low R&D intensity of Japanese affiliates in the United States reflects the relatively low percentage of Japanese FDIUS directed to manufacturing: in 1992, 19 percent of Japan's FDIUS was in manufacturing and 34 percent in wholesale trade, compared with 47 percent and 8 percent, respectively, for European FDIUS.[20]

Table 4-1 shows cross-national variations in the sectoral focus of manufacturing R&D by foreign affiliates in 1992. The distribution of spending reinforces the above observation that the average R&D intensity of foreign affiliates varies with respect to the sectoral distribution of FDIUS. However, there are also notable cross-national differences in R&D intensity within individual sectors. As table 4-2 shows, in 1992 the average R&D intensity for all foreign affiliates in U.S. manufacturing industries was 2.7 percent; the average for German affiliates was 3.5 percent, while it was 2.9 for French affiliates, 2.2 for U.K. affiliates, and 1.7 percent for Japanese affiliates. Across the major industrial sectors, German affiliates typically have the highest R&D intensity levels and Japanese affiliates the lowest, while U.K. and French affiliates share the middle ground.

In short, the scope and intensity of R&D by foreign affiliates in the United States varies both by country and by sector. Most of the manufacturing R&D conducted by foreign affiliates in the United States is concentrated in industrial chemicals, drugs, and electrical and electronic machinery (see figure 4-4). In these areas the R&D intensity of foreign affiliates is two or more times the na-

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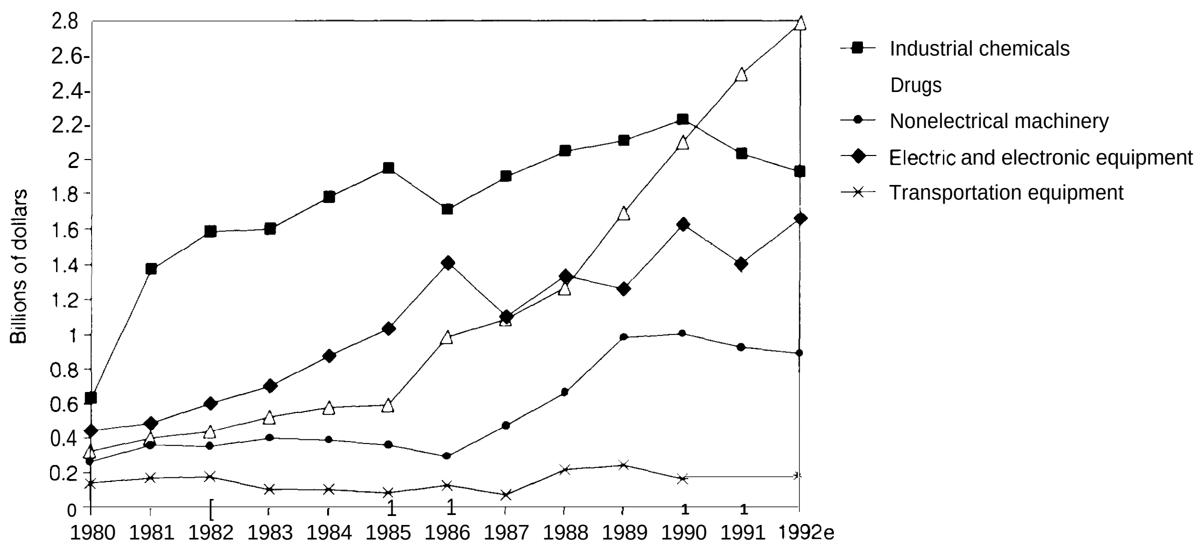
18 R&D intensity is the ratio of R&D expenditures to total output (sales).

19 OECD, *Performance of Foreign Affiliates,* op. cit., footnote 4, table 1, p. 80. For an analysis of FDIUS by country and by sector, see ch. 5 of this report.

20 U.S. Department of Commerce, BEA, *Foreign Direct Investment in the United States: Preliminary 1992 Estimates,* op. cit., footnote 12. See chapter 5 for a complete analysis of the composition of FDIUS.

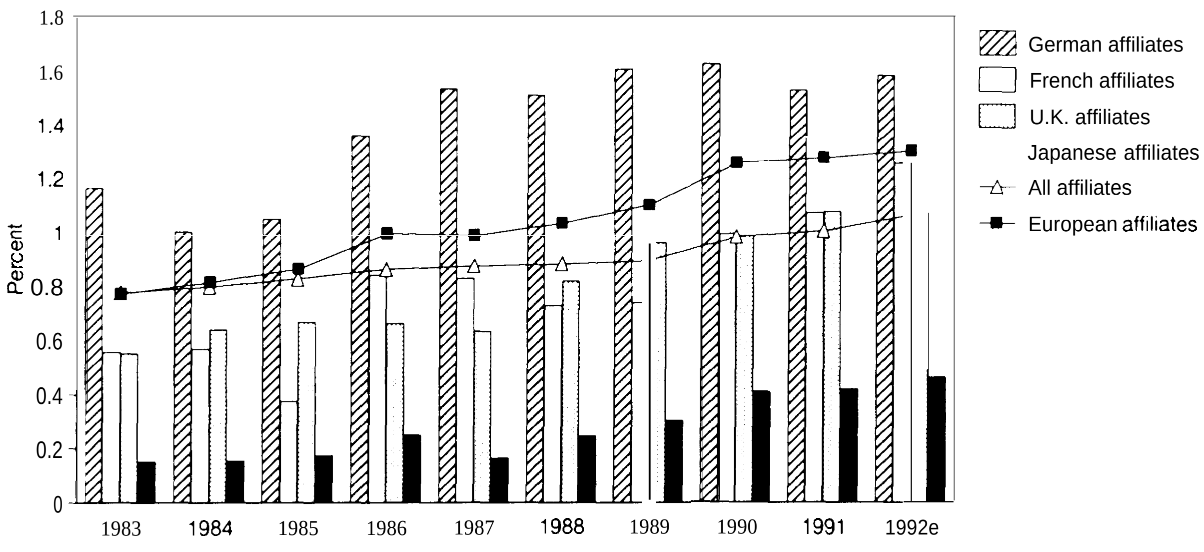
FIGURE 4-4: Manufacturing R&D Expenditures of Foreign Affiliates in the United States by Sector, 1980-1992 (constant 1987 dollars)



NOTE 1992 data are preliminary

SOURCE OTA based on data m ESA, *FDIUS*. appendix C, table 56, BEA. *FDIUS*. table H-1 (1987-1992)

FIGURE 4-5: R&D Intensity of Foreign Affiliates in the United States by Nationality of Ownership, 1983-1992



NOTES R&D intensity measures total affiliate R&D expenditures as a percent of total sales 1992 data are preliminary

SOURCE OTA based on data in BEA. *FDIUS* tables 8 and H-6 (1983-1986) and tables A-6 and H-2 (1 987-1992)

TABLE 4-1: Manufacturing R&D Expenditures of Foreign Affiliates in the United States by Sector, 1992
(millions of constant 1987 dollars)

	All countries	Germany	France	U.K.	Japan
All manufacturing	9,393	1,462	1,007	1,492	981
Chemicals and allied products	5,095	871	239	958	141
Industrial chemicals	1,926	626	n/a	86	53
Drugs	2,787	n/a	n/a	795	63
Machinery	2,549	379	403	141	612
Nonelectrical machinery	894	51	168	46	457
Electric and electronic equipment	1,656	328	235	94	156
Transportation equipment	179	34	26	60	13

SOURCE: Adapted from U S Department of Commerce, Bureau of Economic Analyses, *Foreign Direct Investment* in *the United States Operations o/ U.S. Affiliates of Foreign Companies* preliminary 1992 estimates (Washington, DC U S Government Printing Off Ice, forthcoming), table H-4

TABLE 4-2: Manufacturing R&D Intensity of Foreign Affiliates in the United States, by Sector, 1992
(R&D expenditures as a percent of total affiliate sales)

	All countries	Germany	France	U.K.	Japan
All manufacturing	2,7	3.5	2.9	2.2	1.7
Chemicals and allied products	5.0	4.5	3.2	4.4	2.7
Primary and fabricated metals	0.6	8.0	n/a	69	4.0
Machinery	3.6	3.9	5,7	2.0	3.6
Other manufacturing	1.3	2.0	n/a	12	0.8

NOTE: R&D intensity measures total affiliate R&D expenditures as a percent of total sales, a more complete sectoral breakdown of 1992 affiliate sales data wiIl be available only after this publication has been released

SOURCE: OTA, based on data in U S Department of Commerce, Bureau of Economic Analyses, Foreign D/reef/nves[menf/nfhe *Unded States:* Operations *of U.S. Affiliates of Foreign Companies* preliminary 1992 estimates (Washington, DC U S Government Printing Office, forthcoming), tables E-4 and H-4

tional average for all industries.[21] Affiliates in these sectors (mostly Swiss, German, U. K., and Japanese firms) are technologically and commerc i ally powerful global competitors, and can mobilize substantial R&D resources. Moreover, the fact that they concentrate R&D resources in the United States indicates the attractiveness of the U.S. market for companies that have successfully developed new technologies.[22]

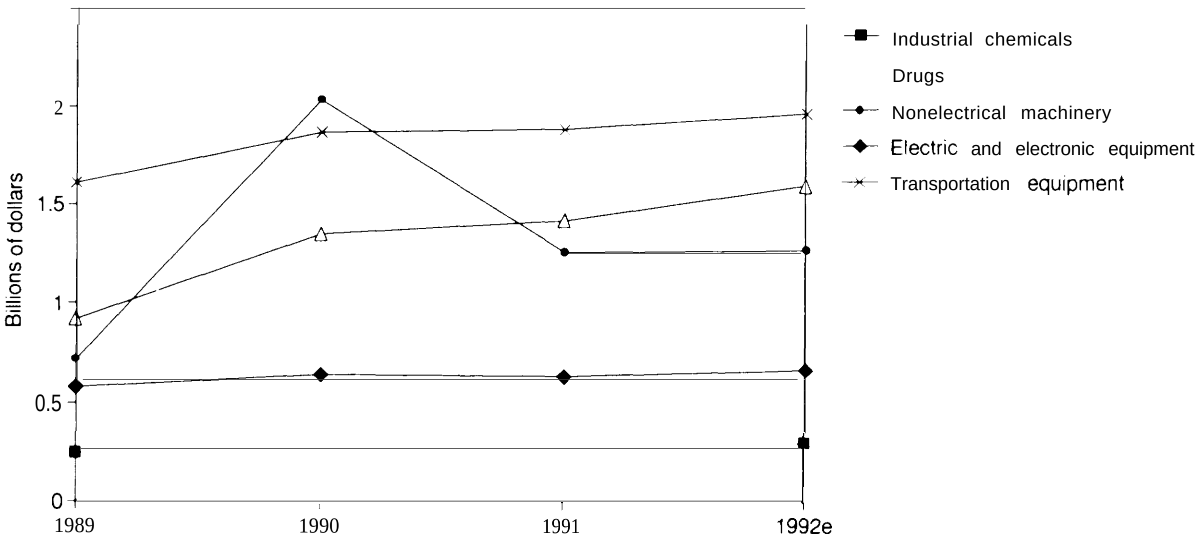
R&D by U.S. Affiliates in Foreign Markets

Like the R&D activity of foreign affiliates in the United States, the overseas R&D by affiliates of

21 In most countries, the R&D intensity of affiliates is lower or at most equal to the average R&D intensity for all manufacturing industries in host countries. The United States is one of the few exceptions to this tendency. OECD, *Performance of Foreign Affiliates*, op. cit., footnote 4, p. 5 I .

22 Ibid.

FIGURE 4-6: R&D Expenditures of U.S. Affiliates in Foreign Markets by Sector, 1989-1992 (constant 1987 dollars)



NOTE: 1992 data are preliminary.

SOURCE: OTA based on data in U.S. Department of Commerce, Bureau of Economic Analysis, *U.S. Direct Investment Abroad Operations of U S Parent Companies* and *their Foreign Affiliates* revised 1989-1991 estimates and preliminary 1992 estimates (Washington DC U S Government Printing Office, 1992-1994) table III I 2-5 (hereafter cited as BEA, *USDIA)*

U.S. MNEs has increased rapidly over time. Between 1982 and 1992, R&D expenditures by majority-owned foreign affiliates of U.S. MNEs increased from $4.3 billion to $8.4 billion in real terms.[23] Also like foreign affiliates in the United States, the location and character of this R&D activity varies by country arid by sector.

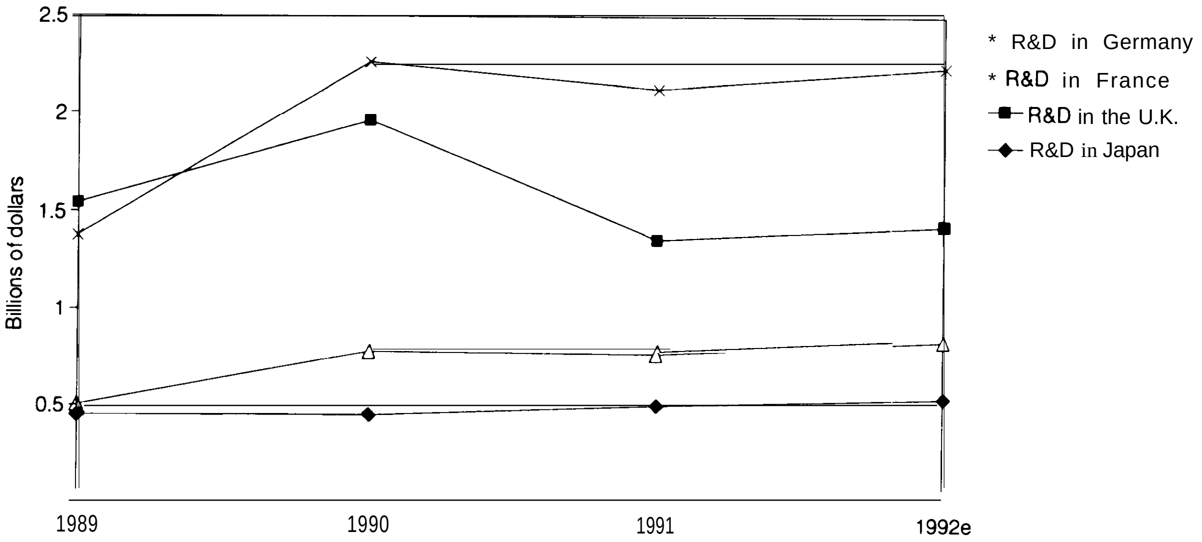
Most of the overseas R&D conducted by U.S. affiliates is in manufacturing. Between 1989 and 1992, manufacturing R&D accounted for an average of 84 percent (or $6.7 billion) of all R&D spending by U.S. affiliates in foreign markets .24 This ratio is equivalent to the average of 86 percent for the manufacturing R&D of foreign affiliates in the United States. However, while R&D by affiliates in the United States is concentrated in chemicals, pharmaceuticals, and machinery, the R&D by U.S. affiliates abroad is focused on machinery and transportation equipment. Of total overseas manufacturing R&D by U.S. affiliates between 1989 and 1992,29 percent was in electrical and nonelectrical machinery combined, 27 percent in transportation equipment, 20 percent in pharmaceuticals, and just 4 percent in chemicals (see figure 4-6).[25]

[23] U.S. Department of Commerce, BEA, *Survey of Current Business* (Washington, DC: July 1993), table 5, p.44; and U.S. Department of Commerce, BEA, *U.S. Direct Investment Abroad: Preliminary 1992 Estimates* (forthcoming, 1994), table 111.13. Data adjusted to constant 1987 dollars.

[24] U.S. Department of Commerce, BEA, *U.S. Direct Investment Abroad,* annual series (Washington, DC: 1992-1 994), tables 111.13 and III.E 3. The R&D data in this series goes back only to 1989. Data adjusted to constant 1987 dollars.

[25] U.S. Department of Commerce, *U.S. Direct Investment Abroad: Preliminary 1992 Estimates*, op cit. footnote 23.

FIGURE 4-7: R&D Expenditures of U.S. Affiliates in Foreign Markets by Country, 1989-1992 (constant 1987 dollars)



SOURCE: OTA, based on data in BEA, *USDIA,* table III.I.3 (1989-1992)

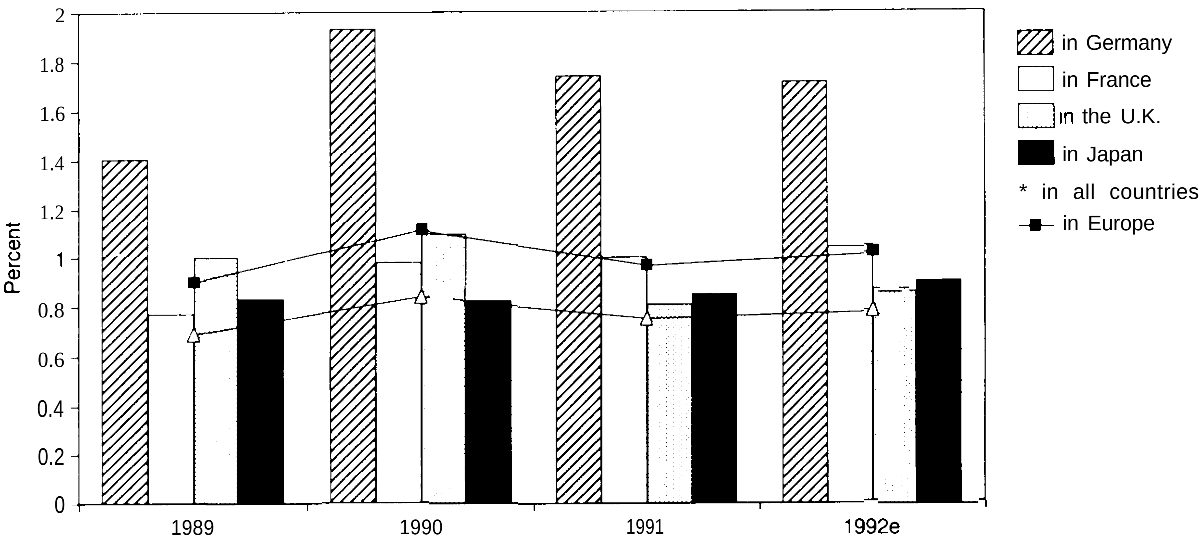
By country, the distribution of R&D expenditures by U.S. affiliates mirrors that of foreign affiliates in the United States. In relative terms, R&D by U.S. affiliates is concentrated in Germany and to a lesser extent the United Kingdom, with comparatively little R&D in France and Japan (see figure 4-7). Between 1989 and 1992, U.S. affiliates on average spent $2 billion per year in Germany (25 percent of the total by U.S. affiliates) and $1.6 billion per year in the United Kingdom (20 percent of the total), compared with $722 million (9 percent) in France and $488 million (6 percent) in Japan.

Like foreign affiliates in the United States, U.S. affiliates abroad have higher R&D intensities in the markets where they are more concentrated in manufacturing industries (see figure **4-8).** In 1992,96 percent of R&D by U.S. affiliates in Germany was in manufacturing industries; the same ratio for the United Kingdom was 83 percent, while it was 76 percent for France and 80 percent for Japan. Of the $2.2 billion in manufacturing R&D conducted by U.S. affiliates in Germany, 59 percent ($1.3 billion) was in transportation, 14 percent in machinery, and 11 percent in chemicals and allied products. In the United Kingdom, 38 percent ($462 million) of the manufacturing total ($1.2 billion) was in chemicals and allied products, and 18 percent was in machinery. In France, 63 percent ($402 million) of the total $641 million in manufacturing R&D was in chemicals and allied products. And in Japan, 49 percent ($213 million) of the total $437 million in manufacturing R&D by U.S. affiliates was in chemicals and allied products, while 32 percent ($ 139 million) was in machinery (of which 74 percent or $103 million was in electric and electronic equipment).zc

In sum, the R&D activities of both foreign affiliates in the United States and U.S. affiliates abroad have increased significantly in recent years, but the scope and intensity of that activity

26 ibid. All amounts have been converted to constant 1987 dollars.

FIGURE 4-8: R&D Intensity of U.S. Affiliates in Foreign Markets by Country, 1989-1992



NOTES: R&D intensity measures total affiliate R&D expenditures as a percent of total sales, 1992 data are preliminary

SOURCE: OTA based on data in U S Department of Commerce, Bureau of Economic Analysis, Survey *of Current Business* 73(7) 53-54 table 11 1 and 112 July 1993 (hereafter cited as BEA, SCB): BEA, *USDIA,* table III I 3 (1 989-1 992)

varies by country and by sector. The magnitude and intensity of R&D activity is the highest between the United States and Germany and the United Kingdom, in both directions; likewise, the magnitude and intensity of R&D activity is the lowest between the United States and France and Japan, also in both directions.

Although these measures of R&D activity provide useful indicators of the magnitude of R&D conducted by MNEs in host countries, they do not provide sufficient information to judge whether R&D has become significantly more decentralized during recent years. For instance, the rise in R&D by affiliates may represent acquisitions of foreign R&D facilities more than the transfer of research from the home market to foreign sites. In addition, R&D spending data do not distinguish between types of technology and types of R&D, which makes it difficult to assess the character and import of R&D conducted in different locations.

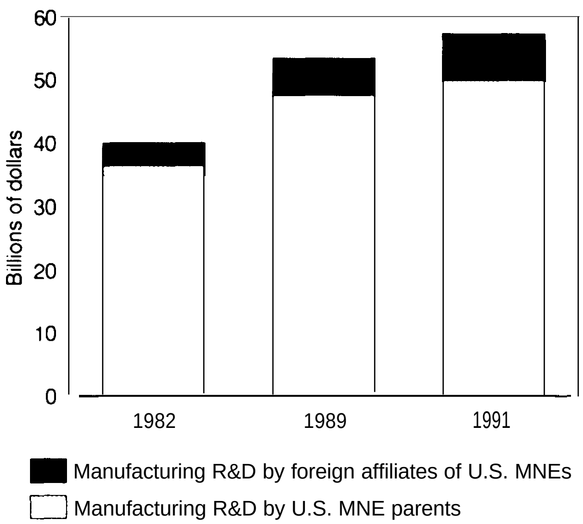
In short, assessing the scope and impact of R&D by MNEs requires a more detailed comparison of the R&D conducted by affiliates with that conducted by their parent groups in their home markets.

R&D Within Multinational Networks

Although the volume of overseas R&D by affiliates has increased substantially, it is still a small fraction of the total R&D conducted by MNEs. The domestic and overseas R&D conducted by U.S.-based MNEs since the early 1980s illustrates both of these points (see figure 4-9). Between 1982 and 1991 manufacturing R&D expenditures by U.S. MNE parents increased an average of 4.8 percent per year, from $36.5 billion to $50 billion. During the same period manufacturing R&D spending by affiliates of U.S. MNEs grew at a faster rate of 12.1 percent per year, rising from $3.5 billion to $7.2 billion.[27] The faster rate of growth of R&D by affiliates indicates that R&D

[27] Adjusted to constant dollars from data provided in U.S. Department of Commerce, BEA, *Survey of Current Business*, op. cit. footnote 23. See also figure *4-9*.

FIGURE 4-9: Manufacturing R&D of U.S.-based MNEs (constant 1987 dollars)



SOURCE: OTA, based on data in BEA, SCB 73(7): 44, table 5, July 1993

has become more international in scope. At the same time, however, the proportion of total MNE R&D conducted by affiliates remains small. In 1991, the R&D conducted by majority-owned affiliates comprised 12.7 percent of the total manufacturing R&D expenditures of U.S. MNEs, up from 8.7 percent in 1982.[28] Although no comparable data exists for European and Japanese MNEs, the available evidence suggests that they conduct similar if not smaller percentages of their R&D overseas than do U.S. firms.

Like the aggregate level of R&D spending, the R&D intensity of foreign affiliates tends to be substantially lower than that of parent groups. For example, the R&D intensity of U.S. MNE parent groups in 1991 was 2.1 percent, compared with 0.8 percent for their majority-owned foreign affiliates.[29] In general, across the advanced industrial states the R&D intensity of foreign affiliates tends to be lower than or at best equivalent to the average for all manufacturing industries in the host country.[30] However, as with the volume of R&D spending, the R&D intensity of foreign affiliates has been increasing at a faster rate than that of MNE parent groups. For example, between 1982 and 1991 the annual growth rate in the R&D intensity of majority-owned foreign affiliates of U.S. MNEs averaged 5 percent, compared with 3 percent for their parent groups.[31] Again, though, much of the growth in the R&D intensity of both foreign affiliates in the United States and U.S. affiliates abroad can be attributed to overseas acquisitions and/or joint ventures, and consequently does not necessarily represent a transfer of R&D operations from the home country to foreign markets.[32]

Although relatively low, the rapid increase in both the magnitude and intensity of overseas R&D by foreign affiliates does represent a gradual globalization of R&D. However, it is extremely difficult to assess the significance of this trend due to the lack of data regarding the technological and strategic contribution of the R&D conducted by

28 Ibid. The proportion of R&D by majority-owned affiliates of U.S. MNEs varies somewhat by sector. In 1991 it was highest in food and kindred products (18 percent), chemicals and allied products (15 percent), and transportation equipment (14 percent), and lowest in electric and electronic equipment (8 percent) and primary and fabricated metals (5 percent).

29 U.S. Department of Commerce, BEA, *Survey of Current Business,* op. cit., footnote 23, table 5, p 44, table 7, p. 46.

30 OECD, op. Cit., footnote 4, p. 51. One of the few exceptions to this rule is the United States, where the average R&D intensity of foreign affiliates is driven up by the particularly high R&D intensity of foreign affiliates in pharmaceuticals, chemicals, and mechanical engineering (respectively two, three, and four times that of all manufacturing industry in the United States).

31 U.S. Department of Commerce, BEA, *Survey of Current Business,* op. cit., footnote 23, p. 46.

32 For data and analysis of U.S. MNEs see U.S. Department of Commerce, BEA, *Survey of Current Business,* op. cit., footnote 23, p. 46. For an analysis of foreign affiliates in the United States, see U.S. Department of Commerce, BEA, *Foreign Direct Investment in the United States: An Update,* op. cit., footnote 10, p. 70.

foreign affiliates to the global competitiveness of MNEs.[33] Indeed, the most challenging analytical task is to determine whether the R&D conducted by foreign affiliates contributes to the core technological activities of the parent firms, or whether it contributes primarily to the product and process technology utilized by overseas production facilities.

Most studies indicate that, over time and across countries, the most significant reason for conducting R&D in foreign markets is to customize products to accommodate local market conditions.[34] It typically takes quite long for firms to develop complex overseas R&D operations that support local production facilities. For example, Philips Electronics N.V. has maintained a U.S. research facility at Briarcliff Manor, NY, for over two decades. The facility now accounts for approximately 15 percent of all corporate research activity, and is an integral part of Philips laboratory network (the company maintains four laboratories in Europe—the central lab at corporate headquarters in Eindhoven, The Netherlands, plus smaller facilities in France, Germany, and England). While each of the foreign facilities has its own technological capabilities and its own mix of research programs, most basic research is conducted in Eindhoven. The U.S. facility focuses mostly on supporting Philips' substantial U.S. manufacturing facilities.[35] OTA interviews with a number of MNEs in the electronics industry indicate that it takes at least a decade to establish an overseas research facility that can closely support affiliate manufacturing operations.

Fully integrated affiliates that conduct independent product R&D are relatively rare. For instance, Ford Motor Company, after many years of foreign production in Europe and elsewhere, has just begun to reorganize its operations and become a truly global MNE.[36] The company is planning to create a single operating unit, Ford Automotive Operations, that oversees five vehicle program centers (VPCs), each with worldwide responsibilities for the development and production of independent product lines.[37]

In sum, R&D moves overseas much more slowly than production, sourcing, and other business activities. Production facilities often can be established quickly and moved quickly, as market conditions change. By comparison, R&D facilities take a long time to set up and, once established, are very difficult to move. Consequently, most MNEs centralize basic research and product development in the home market, while research oriented toward customization and foreign production support is gradually conducted locally as affiliates become more deeply integrated into local markets.

The tendency for R&D to move overseas slowly, in the wake of foreign direct investment and local production, suggests an R&D life cycle that corresponds to the FDI life cycle discussed in chapter 6. In the initial stages of overseas production, firms tend to use product and process technology developed in the home market. As overseas production units become more established, local R&D activities emerge to customize

33 OECD, op. cit., footnote 4, pp. 49-50.

34 For example, see U.S. Department of Commerce, Technology Administration, Japan Technology Program, *U.S. Research Facilities of Foreign Companies*, prepared by D.H. Dalton and M.G. Serapio, NTIS Pub. No. 93-134328 (Washington, DC: Jan 1993); U.S. Department of Commerce, Technology Administration and The Japan-U.S. Friendship Commission, *Japan-U. S. Direct R&D Investments in the Electronics Industries*, prepared by M.G Serapio, NTIS Pub. No. 94-127974 (Washington DC: 1994); OECD, op. cit., footnote *4.*

35 On Philips' R&D operations, see Philips Electronics N. V., *Annual Report 1993* (Eindhoven, The Netherlands, 1994); Philips Electronics N. V., "Electronics for People," Corporate Brochure (Eindhoven, The Netherlands, 1993), p. 13; Philips Research, "Philips Research A Gateway to the Future," Corporate Brochure (Eindhoven, The Netherlands, 1993).

36 For distinctions between "global" and other types of MNEs, see box 1-1 in chapter 1.

37 Kevin Done, "Tomorrow, the World," *Financial Times*, Apr. 22, 1994, p. IS.

products in accordance with local market conditions and, eventually, to support affiliate production operations. In advanced stages, as affiliates become deeply integrated into local economies, they may undertake more substantial forms of R&D to develop products exclusively for the local market. Few firms reach this last stage.

If this R&D cycle is the rule rather than the exception, then one would expect overseas R&D to be more pronounced for European affiliates in the United States than for their Japanese counterparts, and likewise more pronounced for U.S. affiliates in Europe than for Japanese affiliates. To some extent the evidence is consistent with this expectation. Both the magnitude and intensity of R&D conducted by European affiliates in the United States is substantially higher than R&D by Japanese affiliates. Similarly, recent studies of Japanese investment in Europe indicate that Japanese affiliates conduct substantially less R&D there than do U.S. affiliates.[38]

This pattern, however, could be attributed to one or more of several different factors. First, it could represent a life-cycle effect, such that Japanese affiliates would eventually reach R&D levels achieved by U.S. affiliates in Europe and European affiliates in the United States. Second, it could reflect differences in the composition of FDI. By this account, the difference in R&D intensities between European and Japanese affiliates in the United States is due to the comparatively large percentage of European investment in manufacturing industries, which account for far more R&D per unit of sales than other areas of FDI.[39] And third, the pattern could be due to different national propensities to conduct R&D overseas, as opposed to other methods of acquiring technology in foreign markets.

Moreover, the degree to which R&D is centralized or decentralized often conforms to different technological and sectoral characteristics. For instance, one of the reasons pharmaceutical companies conduct R&D overseas is to accommodate different national regulatory standards and prac(ices.[w] In the consumer electronics industry, firms often conduct R&D abroad to keep in touch with leading-edge technological developments as well as to adapt technologies to local standards, such as different voltages or broadcasting systems.[41] In the automotive industry, the uniform nature of core technologies tends to encourage centralized R&D, even though production has become highly globalized.[42] In the semiconductor industry, the high R&D component of new product costs is pressuring firms from different countries to collaborate on next-generation product development.[43]

Nevertheless, even when R&D trends are observed on a sectoral basis, there are notable variations in the degree to which MNEs based in different countries conduct R&D in foreign markets. For instance, in the pharmaceutical industry, U.S. firms have set up more secondary R&D facilities than MNEs based elsewhere; European pharmaceutical firms tend to locate their second-

38 M. Gittelman and E. Graham, "The Performance and Structure of Japanese Affiliates in the European Community" in M. Mason and D. Incarnation, *Does Ownership Matter? Japanese Multinationals in Europe,* (Oxford, UK: Clarendon Press, forthcoming 1994), pre-publication copy pp. 154-55.

39 See chapters 5 and 6 for a description of differences in the composition of FDI across the Triad.

40 OECD, "Globalisation in the Pharmaceutical Industry," draft manuscript dated Mar. 10, 1993, p. 9.

41 D.E. Westney, .. Cross-Pacific Internationalization Of R&D by US and Japanese Firms," *R&D Management* 23(2): *171-181,* 1993; OECD, "Globalisation of Industrial Activities: Sector Case Study of Globalisation in the Consumer Electronics Sector,' 'draft paper dated Nov. 9, 1993, p. 17.

42 R. Miller, "Global R&D Networks and Large-Scale Innovations: The Case of the Automobile Industry," *Research Policy* *~(~) :27-46, May *1993. See* also Pavitt and Patel, op. cit., footnote 7. As noted above, though, Ford recently embarked on a strategy that involves decentralizing some of its product R&D.

43 The chip development alliance between IBM, Seimens, and Toshiba is frequently cited in this regard.

ary R&D facilities in the United States, while Japanese pharmaceutical firms have very little exposure in foreign markets.[44] In the consumer electronics industry, Japanese firms conduct the bulk of their R&D at home, unlike European firms.[45] And in the automotive industry, U.S. firms have long had independent operations in Europe that conduct advanced R&D work. By contrast, Japanese auto producers have only recently begun to establish local technological support operations for their foreign assembly operations.[46]

These sectoral variations are consistent with aggregate national patterns. The U.S. firms conduct more R&D and have higher average R&D intensities overseas than either European or Japanese firms. European businesses, particularly those in Germany and the United Kingdom, conduct far more R&D abroad and have much higher average R&D intensities than Japanese affiliates. However, these tendencies coexist with national differences in the sectoral distribution as well as the timing of FDI. Consequently, it is difficult to judge the relative influence of national origins, sectoral characteristics, or vintage effects on the propensity of firms to decentralize their R&D operations across national borders.

Moreover, even though more R&D is being conducted across national borders, relative to production and sourcing R&D remains highly centralized across the advanced industrial states. For instance, the most R&D-intensive industries---electronics, computers, and pharmaceuticals[47]—are largely global in terms of production, sourcing, and marketing. Nevertheless, R&D in each sector remains relatively centralized. For instance, pharmaceutical firms conduct very little research and basic clinical evaluation outside of the home country,[48] while R&D in the computer industry is among the most highly centralized (a fact some analysts ascribe to domestic support programs that favor local firms).[49] The pattern is much the same in less R&D-intensive industries, especially those where core product technology varies little across national markets. For example, R&D in the auto industry remains relatively centralized, although design custom ization is often conducted locally.[50]

In sum, the evidence regarding the location of R&D leads to two principal conclusions:

1. MNEs are conducting increasing levels of R&D in foreign markets, thereby contributing

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44 OECD, op. cit., footnote 40, pp. 9, 39. In 1989, Japanese pharmaceutical firms commanded only 1.1% of the US market, while European firms commanded 26.7 percent of US market share. The pattern in Europe is similar: Japanese firms have a very low market presence, while US pharmaceutical firms command from 18 percent (in Germany) to 33 percent (in the United Kingdom).

45 OECD, "Globalisation of Industrial Activities: Sector Case Study of Global isation in the Consumer Electronics Sector, " draft paper dated Nov. 9, 1993, p. 17.

46 "Much of their activity is in component testing, procurement and process development, but more substantial product development is slowly gathering pace—the Honda Accord in the United States and the Nissan Primera in the United Kingdom had substantial local design inputs." OECD, "Globalisation of Industrial Activities: Sector Case Study of Globalisation in the Automobile Industry," draft paper dated June 16, 1993, p. 27.

47 Aerospace is also consistently among the top four R& D-intensive sectors. It is not widely analyzed in this report due to its unique relationship to the defense industry as well as its unusually high degree of government regulation.

48 OECD, op. cit., footnote 40, p.9, table 4 p. 42.

49 OECD "Globalization of Industrial Activities: Sector Case Study of Globalisation in the Computer Industy," draft paper dated Sep. 27, 1993, p. 11.

50 Patel and Pavit op. cit., footnote 7; Miller, op. cit., footnote 42. Although the R&D intensity of the automotive industry is low relative to electronics, computers, and pharmaceuticals, it has been increasing over time and is well above the national average for manufacturing industries. OECD, op. cit., footnote 46, p. 10.

to the international expansion of technology. However, R&D across the advanced industrial states remains fairly centralized relative to production and sourcing activities, even in global industries.

2. Overseas R&D conducted by MNE affiliates varies by national origin, by sector, and over time, such that it is difficult to separate these influences analytically. On the whole, European affiliates conduct far more R&D in the United States than do Japanese affiliates. This variance may reflect different national propensities to conduct R&D overseas, although the relationship could also be explained by the distribution and relative age of FDI.

These conclusions can be taken further by analyzing cross-national variations in other technologically significant transactions. Apart from carrying out R&D overseas, MNEs can also extend technology across borders through direct trade.

TECHNOLOGY TRADE

Technology can be transferred in different forms and through various mechanisms, many of which are very difficult to measure. The best available quantitative measure of technology flows is the number of royalty and license fee transactions, representing cross-border sales and purchases of intellectual property.[51] Net sales over purchases constitutes the technology trade balance, which represents both the financial significance of technology transactions and the volume and direction of technology flows.

Until the mid-1980s, many U.S. corporations did not treat their intellectual property as a productive asset—in fact, few corporations even included it on their balance sheets. Throughout the 1980s, however, these companies gradually recognized and harnessed the financial power of their intellectual property. Figure 4-10 shows that sales of U.S. intellectual property, adjusted for inflation, have increased steadily from $8.2 billion in 1986 to $16.7 billion by 1992. Moreover, throughout this period the technology trade balance has remained decidedly positive, rising from a surplus of $6.7 billion in 1986 to $12,6 billion in 1992.[52]

Outside of the United States, few countries have had a positive technology trade balance. In fact, with the exception of the United Kingdom until 1986, no other large OECD country has had a positive balance.[53] Figure 4-11 shows the ratio of sales to purchases for the United States, Japan, France, Germany, and the United Kingdom. Throughout the 1980s and early 1990s the ratio for most countries remained just under one, with the exception of the United Kingdom during the early 1980s. In other words, except for the United States, the major OECD countries export roughly

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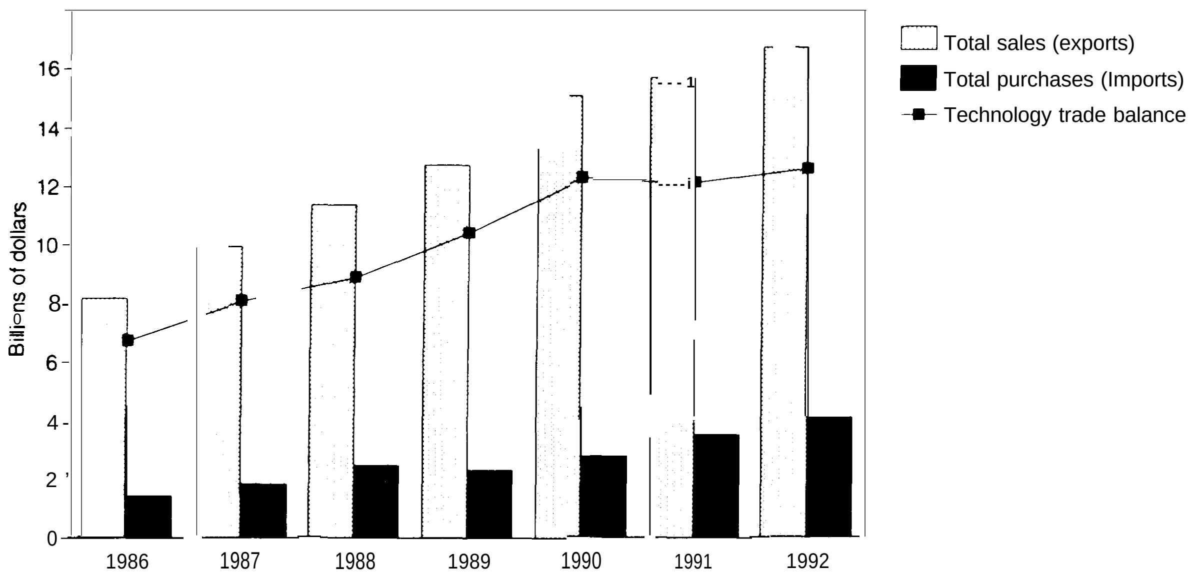
51 This indicator only approximates technology transfer per se, due to three limitations. First, the available U.S. data for royalties and license fees includes transactions of all forms of intellectual property—e.g. it combines industrial process technology along with other forms intellectual property such as copyrights, trademarks, franchises, and rights to broadcast live events. (BEA provides data on industrial process technology only for unaffiliated or arms-length transactions; for a discussion of these transactions see the following pages.) Second, it is difficult to measure intellectual property traded between affiliated firms, since the value of affiliated transactions is not always determined on the open market. Although MNEs dispute the contention, many observers believe that both U.S. and foreign MNEs adjust intellectual property fees to shift costs from their firms in low-tax regions to those in high-tax regions, thereby lowering their net tax obligations. Third, technology also can be transferred through a variety of channels that are not captured by this or any other reliable measure—for instance, technology can be transferred through the exchange of technologically intensive goods, depending on how the purchaser utilizes those goods. Despite these limitations, analysts frequently rely on intellectual property transactions to gauge technology transfer by MNEs.

52 Since intellectual property is an intangible good, the U.S. records sales and purchases of intellectual property on the services account, not the merchandise trade account, Sales of intellectual property represent exports, while purchases of intellectual property represent imports. To the extent that intellectual property transactions represent technology exchange, intellectual property sales are equivalent to technology exports, while intellectual property purchases are equivalent to technology imports. (See footnote 51 regarding the accuracy of this measure.)

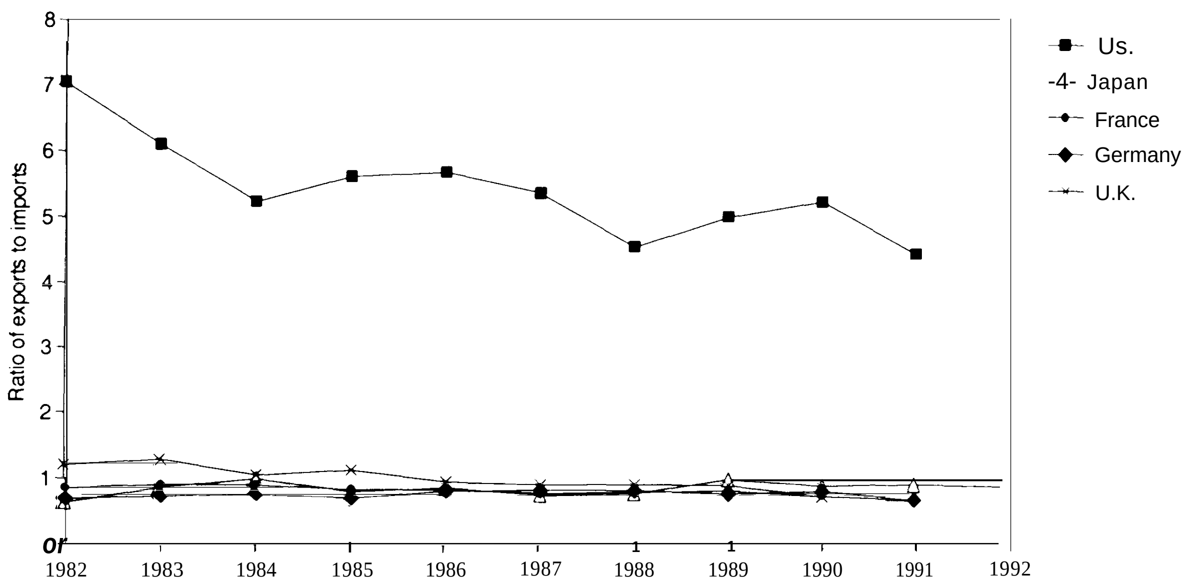
53 Organisation for Economic Co-operation and Development, Economics Analysis and Statistics Division Database, Main *Science and Technology Indicators, (1),* table 82, May 1994.

FIGURE 4-10: U.S. Technology Trade: Royalties and License Fee Transactions, 1986-1992 (constant 1987 dollars)



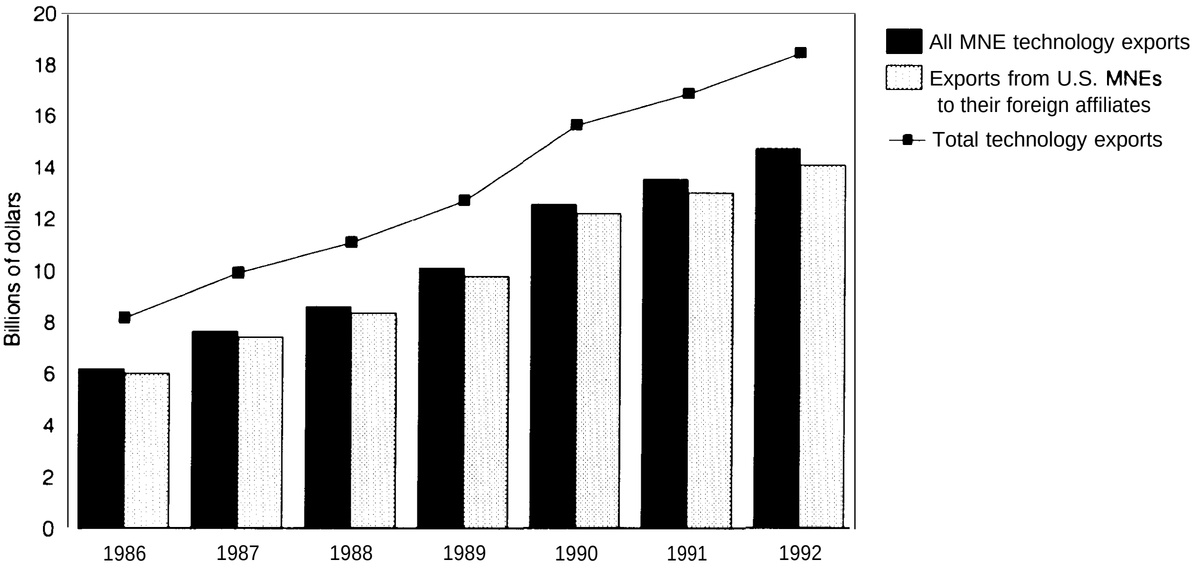
SOURCE OTA, based on data in BEA, *SCB* 73(9) 122, table 2, September 1993

FIGURE 4-11: Technology Trade: Ratio of Technology Exports to Imports by Country, 1982-1992



SOURCE OTA based on data m Organisation for Economic Co-operation and Development Economics Analysis and Statistics Division Database *Main Science and Technology Indicators,* table 82, May 1994

FIGURE 4-12: MNEs and U.S. Technology Exports, 1986-1992 (constant 1987 dollars)



SOURCE: OTA, based on data in BEA, *SCB* 73(9) 122, table 2, September 1993

the same amount of technology that they import. By contrast, U.S. technology exports have consistently outweighed imports by a substantial margin.[54]

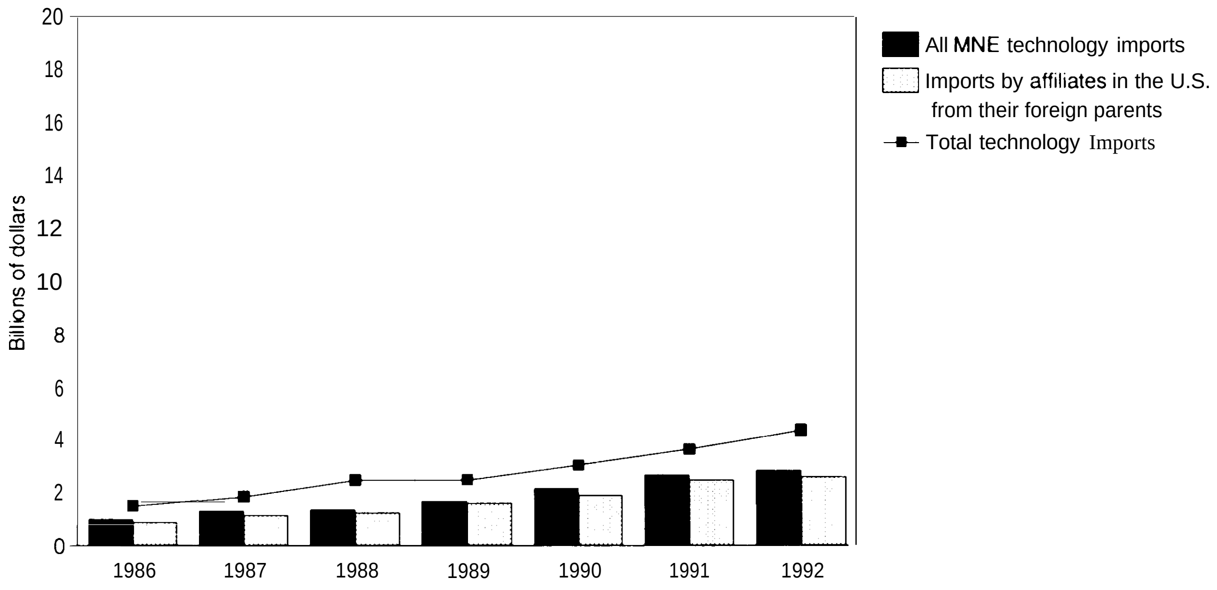
The unusually high U.S. ratio of exports to imports could be interpreted in contradictory ways. On the one hand, it indicates that the U.S. technology base is very robust, producing valuable and highly marketable knowledge that contributes positively to the U.S. trade balance. In this respect, the comparatively high level of technology exports indicates a healthy and vibrant technology base. On the other hand, it could indicate a relatively low willingness or ability of U.S. firms to import foreign technology, which could limit the growth of the U.S. technology base.[55] Moreover, the large surplus of technology exports over imports points to a massive flow of technology out of the country, which also may not bode well for the health of the technology base. Sorting out these conflicting interpretations requires further analysis of the direction and composition of technology trade.

As figures 4-12 and 4-13 indicate, a large percentage of U.S. technology trade is associated with MNEs. Between 1986 and 1992, U.S. MNEs and U.S. affiliates of foreign MNEs together sold

54 This observation holds insofar as intellectual property transactions represent technology exchange per se. The validity Of this indicator is somewhat stronger for OECD data on technology trade than for BEA data on intellectual property transactions, due to slight measurement differences. The available BEA measure covers all intellectual property transactions, which includes patents for industrial process technology along with copyrights, trademarks, franchises, rights to broadcast live events, and other intangible property rights. The OECD measure is more tightly focused on technology trade per se, covering patents, licenses, trademarks, designs, know-how, and closely related technical services for industrial R&D. For the purposes of this analysis, the difference in the two measurements is not significant. This chapter uses OECD data for international comparisons of technology trade, and national data sources such as the BEA for more detailed, country-level analysis of technology trade patterns.

55 See M.E Mogee, "Inward International Licensing by U.S.-Based Firms: Trends and Implications," *The Journal of Technology Transfer 16(2): 14-19,* Spring 1991.

FIGURE 4-13: MNEs and U.S. Technology Imports, 1986-1992 (constant 1987 dollars)



SOURCE: OTA, based on data in BEA, SCB 73(9) 122 table 2, September 1993

79 percent of all technology exports and bought 67 percent of all technology imports. However, the figures also show that U.S. MNEs sell virtually all of the MNE technology exports (see figure 4-12), while U.S. affiliates of foreign MNEs purchase most of the MNE technology imports (figure 4-13). Between 1986 and 1992, 97 percent of all MNE technology exports was sold by U.S. MNEs to their foreign affiliates, while 3 percent was sold by affiliates in the United States to their foreign parents. The obverse pattern holds for imports: 9 percent of all MNE technology imports was purchased by U.S. MNEs from their foreign affiliates, while U.S. affiliates purchased 91 percent of all technology imports from their foreign parents.[56] In short, technology trade not only is dominated by MNEs, but also flows from parent firms to their foreign affiliates.[57]

The rapid increase in both technology exports and imports can be linked to FDI trends during the same period. Between 1986 and 1992, technology exports from U.S. MNEs to their foreign affiliates increased at an average annual rate of 27 percent, which corresponds to the growth in U.S. direct investment abroad during this period. Similarly, during the same period imports by U.S. affiliates from their foreign parents increased at an annual rate of 45 percent, corresponding to the rapid increase in FDI in the United States during the late 1980s.[58]

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[56] U.S. Department of Commerce, BEA, *Survey of Current Business* (Washington, DC: September 1993), table 2 p. 122; see also tables 4.1 - 4.4, pp. 129-132.

[57] Again, this conclusion holds only to the extent that intellectual property transactions represent technology trade.

[58] For trends in FDI in the U.S. see chapters 5 and 6. For data and supporting analysis of the relationship between FDI and technology trade flows, See U.S. Department of Commerce, *Survey of Current Business*, op. cit. footnote *56*, table 4.4 p. 132; and U.S. Department of Commerce, BEA, "U.S. International Sales and Purchases of Private Services," *Survey of Current Business* (Washington, DC: 1992); p.85.

Altogether, the aggregate technology trade data from the mid-1980s to the early 1990s indicate that technology increasingly flows across national borders, but tends to stay within MNE networks.[59] Moreover, the data imply that technology typically is developed in the home market operations of MNEs and gradually extends abroad in the wake of foreign direct investment.[60] From this perspective, one could conclude that technology development remains relatively centralized in the home market operations of MNEs.

However, there are noticeable differences in the propensity of firms based in different nations to trade technology within or outside of MNE networks. Unaffiliated or arms-length technology trade takes place among firms that have no economic relationship other than through the market. Since unaffiliated technology transactions take place through market-based bargaining, they reflect the market value of technology more accurately than trade among firms within MNE networks. Moreover, unaffiliated transactions imply less control by the originator and more control by the purchaser. Consequently, cross-national differences in technology acquisition strategies should be reflected in the propensity of firms based in different countries to purchase technology from unaffiliated sources.

The data on unaffiliated technology trade show that Japanese firms buy an unusually large percentage of U.S. technology through arms-length transactions. In 1992, 43 percent of all U.S. technology sales to Japan were purchased through arms-length transactions. By contrast, 11 percent of all U.S. technology sales to Europe were purchased through arms-length channels, while the percentages of arms-length purchases by firms in the larger European countries were lower than the European average—10 percent for the United Kingdom, 8 percent for France, and 9 percent for Germany.[61] Consequently since unaffiliated transactions impart a higher degree of control to the purchaser, Japanese firms retain greater control over the technology they purchase from the United States than do European firms.

Most of the unaffiliated U.S. technology exports are of industrial process technology. Between 1987 and 1992, industrial process technology accounted for 62 percent of unaffiliated U.S. technology exports. This subset of technology trade is particularly critical to commercial competitiveness, given the direct impact of industrial process technology on productivity and production costs. Consequently, trends in the unaffiliated sale of industrial process technology provide an important indicator of the near-term competitive strategies of MNEs across the advanced industrial states.

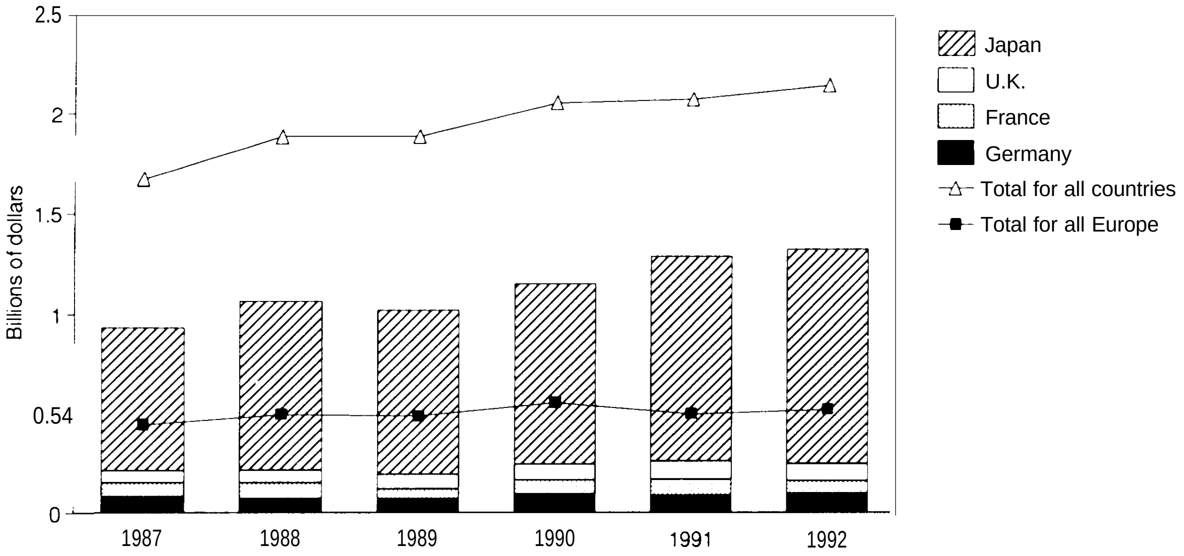
As with total technology trade, unaffiliated U.S. exports of industrial process technology have consistently outweighed U.S. imports, resulting in an average annual surplus of $2.0 billion between 1987 and 1992. Japan is the largest consumer of unaffiliated U.S. industrial process technology—in 1992, U.S. exports to Japan accounted for 50 percent ($1.1 billion in real terms) of all industrial process technology exports, compared with 5 percent for Germany, 4 percent for the United Kingdom, and 23 percent for Europe as a whole (see figure 4-14). This pattern has been consistent; since 1987, Japan has accounted

59 In 1992, 42.5 percent of all U.S. technology imports were by U.S. affiliates of European firms, while 12 percent were by U.S. affiliates of Japanese firms. Likewise, 49 percent of all U.S. technology exports were received by U.S. affiliates in Europe, while 9.4 percent were received by U.S. affiliates in Japan. U.S. Department of Commerce, BEA, *Survey of Current Business,* op cit. footnote 56, p. 121, and table 4.4 p. 132.

60 Data on technology trade between Japan and Europe could provide confirming evidence of this observation. Unfortunately this data is not readily available.

61 Importing patterns by U.S. affiliates of foreign firms are more mixed. In 1992, 64 percent of total U.S. technology imports from Europe were from European MNEs to their U.S. affiliates, although there were large variations among the large European countries—80 percent from the United Kingdom, 63 percent from Germany, and just 38 percent from France. Of all 1992 U.S. technology imports from Japan, 79 percent were purchased by the U.S. affiliates of Japanese MNEs. U.S. Department of Commerce, BEA, op. cit., footnote 56.

FIGURE 4-14: U.S. Exports of Industrial Process Technology to Unaffiliated Firms in Selected Countries, 1987-1992 (constant 1987 dollars)



SOURCE: OTA based on data in BEA, SCB 72(9) 95-99, September 1992, and 73(9) 129-132, September 1993

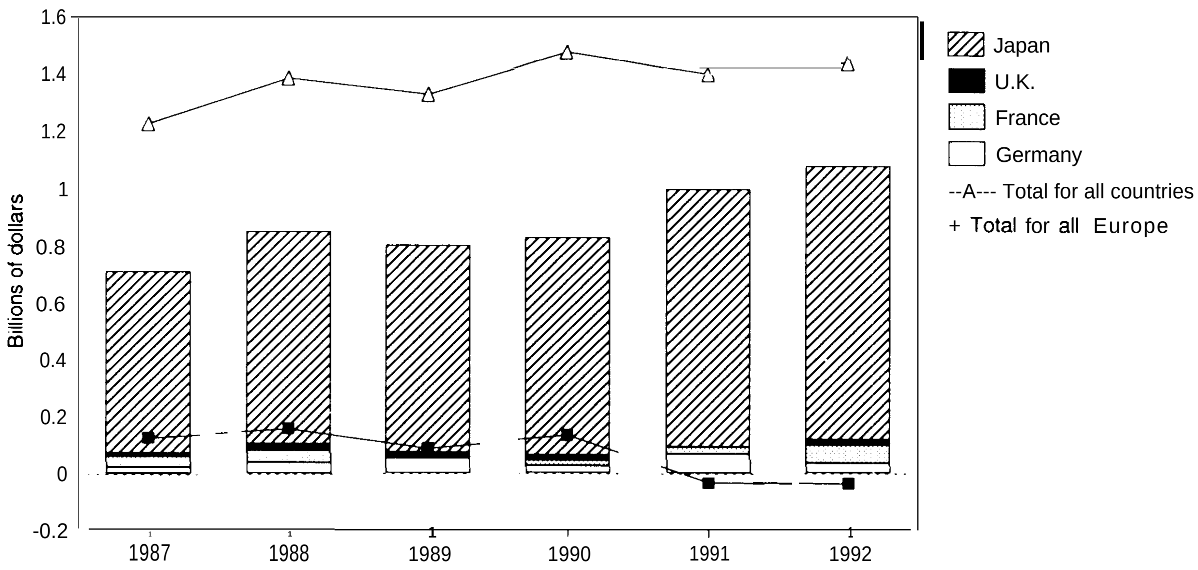
for an average of 46 percent of all unaffiliated exports of industrial process technology, compared with 4 percent for Germany, 4 percent for the United Kingdom, and 26 percent for all of Europe.

The large percentage of unaffiliated industrial process technology purchased by Japanese firms is further reflected in the regional distribution of the U.S. balance in unaffiliated industrial process technology trade. As shown in figure 4-15, the consistent U.S. surplus in unaffiliated industrial process technology exchange is driven largely by trade with Japan. Between 1987 and 1992, the average annual surplus with Japan accounted for 57 percent of the total U.S. surplus in arms-length trading of industrial process technology. During this period Japan ran average annual deficits with the United States of $789 million, compared with $71 million for all of Europe combined. The only countries with which the United States has had a trade deficit in unaffiliated industrial process knowledge have been the United Kingdom and Germany, averaging $-15 million and $-40 million per year respectively between 1987 and 1992.

In sum, U.S. royalties and 1icense fee data illustrate two important patterns in the international exchange of technology. First, most of the cross-border exchange of technology takes place within MNE networks—in particular, most of the technology flows from parents to their affiliates.[62] This pattern implies that, although technology m may follow production overseas, the development of new technology remains centralized in the home market operations of MNEs. Second, there are notable differences in the propensity of firms based in different nations to acquire technology through unaffiliated channels. In particular, Japanese firms purchase far more U.S. technology through arms-length transactions than do European firms-in fact, the total U.S. surplus in the unaffiliated trade of industrial process knowledge is due largely to surpluses with Japan, while the

[62] Again, this conclusion is based on the US technology balance of payments data, which is the (rely available data of this type

FIGURE 4-15: U.S. Unaffiliated Trade Balance in Industrial Process Technology with Selected Countries, 1987-1992 (constant 1987 dollars)



SOURCE: OTA, based on data in BEA, SCB 72(9) 95-99, September 1992, and 73(9) 129-132, September 1993

United States has been a net importer of U.K. and German industrial process knowledge. This finding suggests that MNEs based in Japan have very different technology acquisition strategies than their European and U.S. counterparts.[63]

Although both the R&D and technology trade data indicate that technology development remains relatively centralized, technology can be globalized through other mechanisms such as international strategic alliances and related forms of intercorporite cooperation designed to spread investments costs and gain access to a wider range of technologies. The abundance of interfirm alliances and joint ventures in R&D and product development, along with the growing density of translational networks linking firms with each other as well as with public and private-sector research institutes, significantly complicates any assessment of how MNEs do and do not contribute to technology development in host countries.

INTERNATIONAL TECHNICAL ALLIANCES[64]

MNEs and domestic firms can cooperate on technology development through a variety of

63 Historically, Japan has acquired foreign technology more through direct purchases than has been the case for either the United States or Europe; see OECD, op. cit., footnote 4. The relatively high percentage-of arms-length technology purchases by Japanese firms from U.S. intellectual property owners is consistent with Richard Samuels characterization of the technology acquisition strategies of Japanese firms. See R.J. Samuels, *"Rich Nation, Strong Army": National Security and the Technological Transformation of Japan* (Ithaca, NY: Cornell University Press, I 994).

64 Little enough is known about international technological collaboration among firms that analysts frequently use different terms to describe the phenomenon. There are important distinctions in the literature between short-term tactical alliances and relatively longer term strategic alliances, There are also important distinctions bet ween alliances used to develop and/or diffuse technology and those used to gain market access and pursue other non-technological goals. For simplicity, this chapter uses a single term-international technical alliances—to describe any interfirm collaboration (equity or non equity) that includes arrangements for joint research and/or technology transfer. For a more general discussion of international strategic alliances, see OTA, *Multinationals and the National Interest: Playing by Different Rules*, OTA-ITE-569 (Washington, DC': U.S. Government Printing Office, September 1993), ch. 5. See also box 8-1 in chapter 8 of this report.

mechanisms. In the 1970s, the most common form of international technology collaboration was through joint ventures and research corporations, where firms share equity ownership (and corresponding profits and losses) in a separate and distinct corporate entity. By the late 1980s, joint equity col1aboration was eclipsed by nonequity alliances, in which firms forego formal equity linkages and directly organize joint R&D activities to reduce the cost and risk of pursuing related innovations.[65] Through these mechanisms, international technical alliances have grown from just 86 during 1973-76 to 988 during 1985-88.[66]

The most recent data indicate that international technical alliances are most common in high-technology industries, and are more extensive in some sectors than others (figure 4-16). Technical alliances are particularly prevalent in information technologies, where technology changes rapidly and firms must maintain knowledge of and access to numerous complex technologies simultaneously (as in multimedia, for example). Alliances are also quite common in biotechnology, where research is often conducted in the context of collaborative agreements between U.S. dedicated biotechnology companies and large pharmaceutical MNEs.[67] Figure 4-15 also indicates that alliance activity across sectors is most common between U.S. and European firms, although there have been a relatively large number of alliances between U.S. and Japanese firms in the automotive sector.

Contemporary economic and technological conditions provide a variety of incentives for firms to engage in international technical alliances. Firms pursue technical alliances for three primary reasons:

1. To improve their ability to conduct research, given the complexity and interdisciplinary character of new technologies, the difficulty of monitoring evolving scientific disciplines and new technologies, the need to retain access to scientific and technological knowledge, and the need to reduce the costs and risks of pursuing R&D.
2. To expand their ability to produce new technologies, given shorter innovation to commercialization periods, more rapid product life cycles, and the frequent need to capture competitors' tacit knowledge in order to equilibrate production costs and prevent technological leapfrogging.
3. To pursue market access and search for new business opportunities, given the increasing importance of foreign markets to competitiveness, as well as the need to maintain smooth and broadly dispersed pipelines from innovation to market.[68]

It appears that cooperative research does not substitute for but rather complements firms' internal research activities.[69] Some studies tentatively

65 In very general terms, joint ventures are more common among firms seeking to improve their long-term market position, while techical all lances are more common when firms are pursuing more immediate technological achievements. See J. Hagedoorn, "Understanding the Rationale of Strategic Technology Partnering Interorganizational Modes of Cooperation and Sectoral Differences," *Strategic Management Journal* 14 (1993) 371.

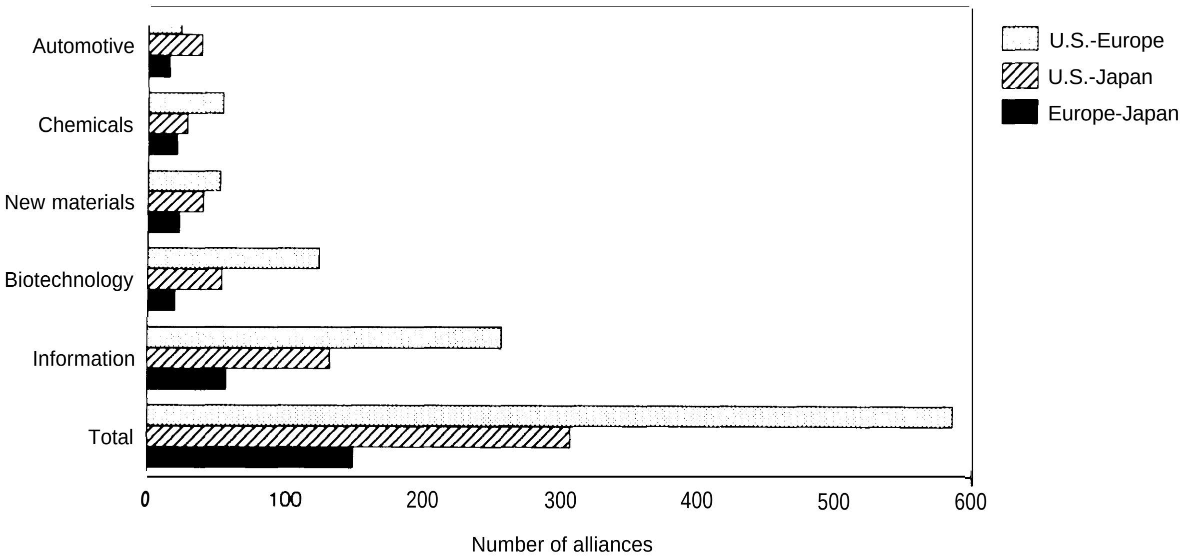
66 *National Science* Board, op. cit., footnote 10, p. 123. The *data* cited in this source is drawn from the Maastricht Economic Research Institutes' MERIT CAT] database. The CATI database covers (rely interfirm agreements that involve technology transferor joint research, and is used to develop the numbers cited above and in figure 4-16. Although this is the best and most up-to-date aggregate database on international technical alliances, it is limited due to intrinsic difficulties in gathering complete and reliable data in this area. T'he data, therefore, should be viewed as a useful but incomplete indicator.

67 MNEs are attracted to the research capabilities of U.S. dedicated biotechnology companies, which are in turn attracted to the financial capabilities of pharmaceutical MNEs.

68 See Hagedoorn, op. cit., footnote 65, p. 371.

69 National Science Board, op. cit., footnote 10, p. 122.

FIGURE 4-16: Sectoral Distribution of International Technical Alliances, 1985-1989



SOURCE: Adapted from National Science Board, Science *and Engineering* /nd/caters—1993 (Washington, DC U S Government Printing Office, 1993), p 123, p 383, table 4-42

conclude that technology transfer invariably accompanies interfirm alliances, and that close management of diffusion is critical to the success of the alliance for each partner.[70] Other studies have concluded that technical alliances tend to be limited and are frequently unsuccessful .[71]

However, systematic and reliable information on international technical alliances is sparse. OTA interviews and other anecdotal information suggest that technical alliance activity has grown significantly in recent years, but the impact of the trend is difficult to assess. Given the increasing R&D content of new products and the escalating cost of developing new products, many high-tech firms are likely to focus their R&D efforts and technology strategy on core competencies, relying on networks of alliances to learn about and adapt to new technologies in related areas. A number of firms interviewed by OTA indicated that they needed to keep abreast of technological developments globally, given the broad dispersion of leading-edge technological capabilities in their industries. An executive at one prominent MNE in the electronics industry told OTA that, although the company has resisted alliance activity to date, it is bound to pursue future alliances due to the increasing complexity and costs associated with R&D in that industry.

Pending further data and analysis of this relatively new phenomena, OTA can only conclude

70 See DC Mowery, "International Collaborative Ventures and U.S. Firms' Technology Strategies," in Granstrand, Håkanson, and Sj~}l~d-er, *Technology Management and International Business (New* York: John Wiley, 1992): 224-229.

71 The literature is rife with debates over the determinants of success in international alliances. Some maintain that success is more common" in alliances that involve technologically comparable firms; for example, see M.E. Porter and M.B. Fuller, "Coalitions and Global Strategy," in M.E. Porter (cd.), *Competition in Global Industries* (Boston, MA: Harvard Business School Press, 1986). Others argue that successful alliances are more likely between firms that have different, complementary technological assets; for example, see Mowery, op. cit., footnote 70. The literature generally does agree that there is insufficient data on international technical alliances to develop reliable interpretations.

tentatively that international technical alliances are indeed more common and more strategically significant for an important array of high-technology firms. Yet their net effect on national technology development and international technology diffusion is unclear and difficult to measure.

CONCLUSIONS

Taken together, the evidence linking MNEs and the globalization of technology remains somewhat mixed. On the one hand, some data point to the increased globalization of technology via the business activities of MNEs. Higher rates of external patenting, more rapid diffusion of technology across borders, increasing rates of overseas R&D activity, and in some respects the increasing prevalence and greater strategic significance of international technical alliances all point in this direction, with MNEs at the heart of the process.

However, closer inspection of these trends indicates that the degree of globalization is limited, and the propensity of MNEs to extend core technological functions across borders varies across the advanced industrial states.

First, overseas R&D by affiliates remains quite limited when compared to both the R&D activities of the parent group and the more extensive globalization of production and sourcing. The R&D that does move overseas tends to be associated with product customization and local production processes. Only rarely do companies transfer basic research functions to foreign markets.[72] In short, inside the corporation-where the bulk of commercially significant innovation takes place—R&D appears to remain relatively centralized. This finding is reinforced by the data on technology trade, which show that most intellectual property flows from parent firms to their foreign affiliates.

Second, data on exports and imports of intellectual property indicate that most of the international flows of technology occur within MNE networks. This tendency does vary by national origin. Japanese firms have a much stronger propensity toward arms-length technology trade, which is consistent with the oft-noted historical tendency for Japanese firms to acquire overseas technology by buying it directly rather than by initiating R&D activities in foreign markets.

Third, the role of international technical alliances appears to be somewhat limited, although the data are insufficient to draw any solid conclusions in this area.

These conclusions should be qualified in light of the difficulties of measuring technological innovation and diffusion. The available measures of R&D are biased toward the research side of the innovation equation, and may miss commercially significant forms of technology development and diffusion. Some analysts have argued that important elements of national technological capabilities lie in tacit forms of knowledge—that is, forms of technical knowledge that can be extremely important to successful commercialization and production but that are embodied in both people and organizations in ways that are difficult to measure and evaluate.[73] In addition, new technology can be transferred across borders in the form of goods themselves, which can be reverse engineered to reveal (and perhaps reconstruct) particular technological innovations. Therefore, it is possible that MNEs, with their ability to transfer people, organizational assets, and goods across borders, in effect may diffuse technology far more extensively through their overseas production facilities than can be captured by the measures used in this chapter.

Nevertheless, the measures reviewed here are sufficient to conclude that the core research and development activities of MNEs remain relatively centralized in the home market. If MNEs were extensively and systematically developing and dif-

[72] One exception to this tendency is biotechnology, where a number of European and Japanese MNEs have close basic research contacts and arrangements with small U.S. biotechnology" firms.

[73] Alic, op cit. footnote 2.

fusing technology abroad, it would register in the overseas R&D data as well as the technology trade data. To date, the evidence reveals that MNEs are indeed moving more technology across national borders, but that the extent of this process is quite limited in comparison to the global production and sourcing activities of MNEs. This conclusion implies that the globalization of technology is less an autonomous force that is shaping and integrating national economies and more a multifaceted process that centers on networks of firms with strong roots in distinct national innovation systems.