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# Internationalization of Research and Development in Multinational Corporations in the Federal Republic of Germany

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**Deutsches Institut für Wirtschaftsforschung**

Discussion Paper No. 106

# Internationalization of Research and Development in Multinational Corporations in the Federal Republic of Germany

by
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# 1 Introduction

In the course of globalizing their activities, multinational enterprises are increasingly conducting research and development (R&D) in their foreign affiliates. In doing so, they not only back up production abroad and adapt products to meet the requirements of regional markets but also make growing use of the respective national research environment to enhance the efficiency of intra-group research. Research findings are diffused world-wide between group companies (parent companies and their affiliates), so that the place where spending on R&D occurs and the place where it finds application are more and more different.

In the studies on the technological competitiveness of the Federal Republic of Germany being carried out by the DIW in a current research project[1], the following questions are consequently important:

- How does growing world-wide specialization in research and development within multinational corporations affect the technological competitiveness of nations?
- Under what conditions can nations profit from this global specialization in the research and production of multinationals?

In order to provide an empirical answer to these questions on the macroeconomic level, indicators must be found to show how and to what extent parent companies and affiliates sited in the country interlock with the international R&D networks of multinational enterprises. For this purpose, it is necessary to draw not only on the data on production and research of all businesses in the country traditionally compiled in terms of location, but also on data aggregated in an ownership-based framework, separately by businesses owned by nationals within the country and elsewhere, and by businesses within the country owned by foreigners.

We begin in section 2 of this paper with a summary of the international debate on the influence multinational corporations exert on the technological competitiveness of nations. In sections 3, 4, and 5, a variety of data is used to demonstrate the foreign interlinkage of multinational enterprises in the Federal Republic of Germany in production and in research and development. Section 5 examines aspects of the internationalization of research and development in multinational enterprises with respect to the large German chemical companies, taking as an example the interests of German and American firms in each other's countries.

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[1] First results have been published in Schumacher et al. (1995).

## 2 Addressing the ownership concept

Internationally, physical capital (corporate fixed assets, infrastructure) and labour are largely immobile, in other words they are available as factors of production only in the location where they originate. Knowledge, by contrast, has a certain degree of international mobility (Figure 1). Knowledge is disseminated by being applied and through consumption of the products in which it is embodied. Knowledge becomes mobile and imitable in proportion to its disengagement from the minds of research and development scientists, that is to say from human capital. Mobile knowledge can hence:

- be marketed in the form of unembodied knowledge in knowledge-specific forms of distribution (books, structural drawings, software, training courses) and in products of embodied knowledge (machines, equipment, materials, semi-finished goods), or;
- be transferred predominantly in unembodied form between companies within a group without the mediation of the market.

The international mobility of knowledge permits companies in a group to have access through their R&D network to knowledge resources available at other locations. Multinationals can transfer self-generated mobile knowledge particularly rapidly within the group and to production sites throughout the world. For the purpose of recording mobile knowledge in the form of knowledge resources available to businesses, the ownership-based framework is better suited when considering multinational enterprises than the traditional location-based framework, within which most national and international statistics are compiled.[2] There are two fundamentally different statistical-data collection concepts for determining the behaviour of firms in relation to the utilization of production factors:

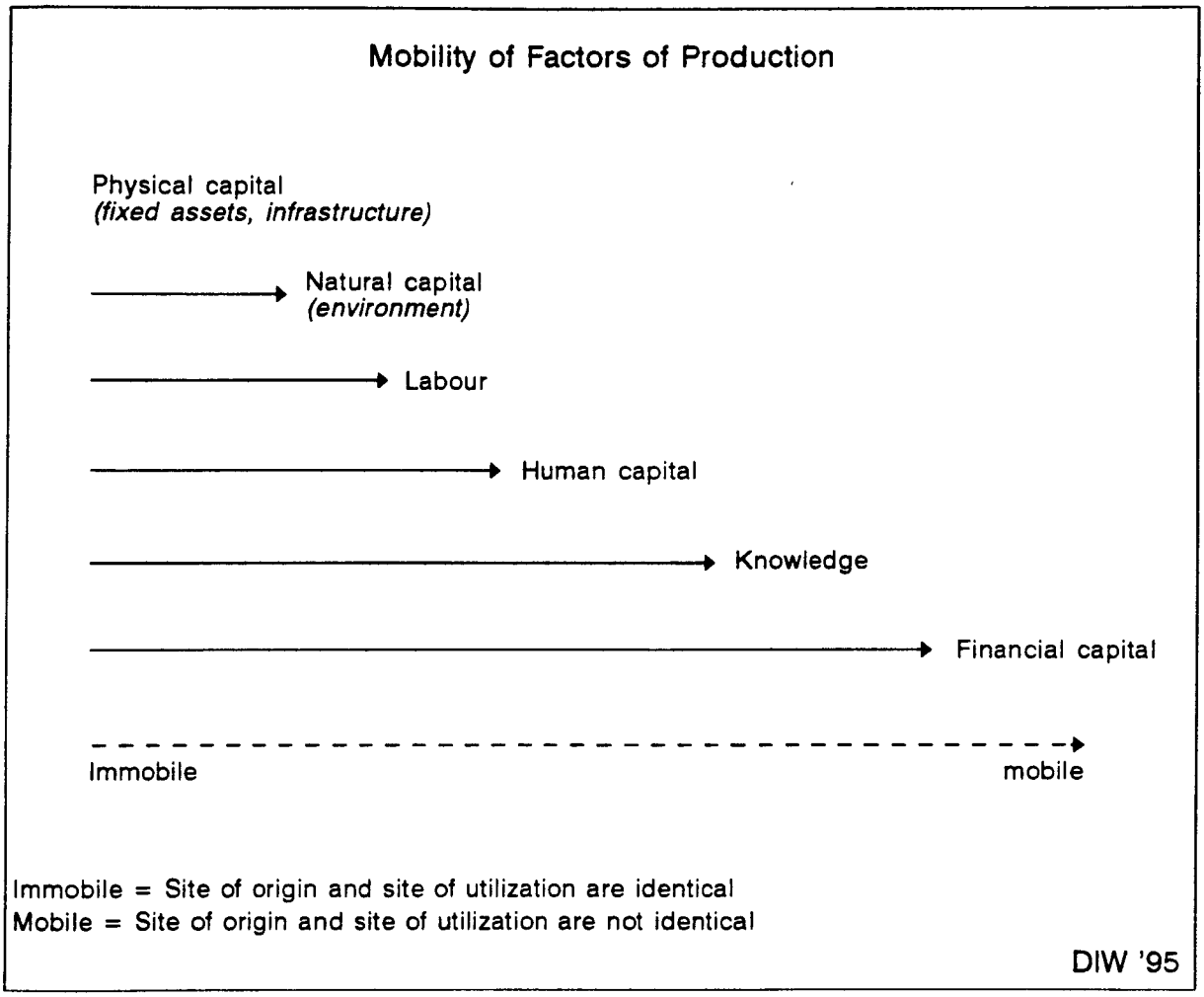
- The *location-based framework*, in which businesses situated in the same location and which make use of the immobile factors of production on the given site are considered together,

and

- The *ownership-based framework*, which brings together businesses in all locations that belong to domestic parent companies. Factors of production available to multinational enterprises in other locations are thus also taken into account.

[2] See Landefeld, Whichard and Lowe (1993).

Figure 1


Mobility of Factors of Production
Physical capital
(fixed assets, infrastructure)
Natural capital
(environment)
Labour
Human capital
Knowledge
Financial capital
Immobile
mobile
Immobile = Site of origin and site of utilization are identical
Mobile = Site of origin and site of utilization are not identical
DIW '95

With the spread of multinational enterprises, the ownership-based concept is also growing in importance for assessing locational performance. The division of labour between parent companies and foreign affiliates can be assumed to influence how income and productivity will develop at a given location. Whereas the locational concept records only flows of income to and from other countries, the ownership concept provides information on the activities of affiliates abroad and the parent companies at home. In a current balance for the Federal Republic of Germany recorded in terms of the ownership-based framework, 'external trade' is thus the exchange of goods and services between:

- German firms in Germany and abroad;

and

- Foreign firms in Germany and abroad.

The National Academy of Sciences (NAS) in the United States and DeAnne Julius in Britain have put forward two methods for preparing a balance on current account in an ownership-based framework that takes account of international transactions by multinational enterprises. Whereas the American balance on goods and services for 1991 showed a deficit of $28 billion when prepared in accordance with the locational concept, calculation in accordance with the ownership concept showed surpluses of $164 billion (NAS) or $24 billion (DeAnne Julius). In addition, a further so-called residency-based framework was developed, combining the location and ownership-based concepts by including in the location-based current account the net effect of the outputs of own affiliates abroad and foreign affiliates at home. In terms of this residency-based framework, the United States had a current account surplus in 1991 of $24 billion.[3]

Reporting on the technological competitiveness of the Federal Republic of Germany has hitherto been based on the locational concept. For this area of inquiry, too, the importance of the ownership-based framework is increasing as R&D activities become more global, especially in multinational corporations conducting research within the group at a different locations around the world. To obtain an 'expanded' locational view, the locational and ownership concepts must be meshed to determine the knowledge resources of a location while taking account of the knowledge available abroad. In this chapter, pointers are given on the utilization of the ownership-based framework to determine domestic firms' global knowledge resources so that additional indicators can be obtained for their technological competitiveness and the productivity of the Federal Republic of Germany as a whole.

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[3] See Landefeld, Whichard and Lowe (1993).

**Globalization of research and development in multinational corporations and the competitiveness of locations**

The share of research done by many multinational enterprises outside the mother country is growing. In this connection, English and American economists in particular have been looking into the question of the effects of foreign direct investment and the related knowledge flows on the technological competitiveness of locations. In Germany, too, the issue has been attracting increasing attention in recent years. Various studies have come to a variety of conclusions regarding the competitiveness of locations of the parent companies (home country) and affiliates (host country), depending on the aspect of the problem under consideration and the indicators for technological competitiveness selected. If one treats the mobility of knowledge only as the transfer of knowledge from parent companies to affiliates, there are two cases of interrelation between knowledge flows and locational competitiveness:

(1) Outward knowledge transfers from domestic parent companies (home country) to affiliates abroad and their impact on the home country;

(2) Inward knowledge transfers from foreign parent companies to domestic affiliates (host country) and their impact on the host country.

Furthermore, the globalization and decentralized networking of research and development are augmenting knowledge flows from affiliates to parents as well as between affiliates throughout the world. The range of cases to be investigated must be extended to include:

(3) Inward knowledge transfers from domestic affiliates located in other countries to parents and sister firms at home (home country) and their impact on the home country;

and

(4) Outward knowledge transfers from foreign affiliates at home (host country) to parents and associated firms abroad, and their impact on the host country.

Klodt regards the Federal Republic as only a technology producer in the international exchange of knowledge (cases 1 and 4) and comes to the following conclusion on the research-intensive industries with outflowing mobile knowledge: 'For the Federal Republic of Germany, which has long ranked high on the international income scale, international technology transfer is to be equated with a loss of competitiveness in regard to technology-intensive products.'[4]

[4] Klodt (1990), 72.

Berthold also takes account of the possibility of the inflow of mobile knowledge from abroad (case 2): 'But since this knowledge [the technological knowledge already existing world-wide] is primarily transferred within enterprises, it is necessary to induce businesses disposing of knowledge to set up in one's own national economy.' Then technological progress would not have to be repeated step by step; one could rapidly advance to the cutting edge of technological research. To achieve this, Berthold calls for:

- Attractive conditions for direct investment;
- Qualified labour and consistent competition policy facilitating company entry into markets for commodities;
- Attractive conditions for executive professionals through whom knowledge is transferred within the enterprise and open factor-markets permitting the unproblematic movement of knowledge enriched in production factors and intermediate inputs within the enterprise.[5]

From this perspective, foreign direct investment in the high-technology sector is generally assessed as favourable, and any negative impacts of technology transfer on the technological potency of the location targeted by direct investments are not recorded.

Cantwell and Dunning investigated case 2 (knowledge flows from foreign group companies) for Britain. Their analysis of the British motor vehicle and pharmaceuticals industries leads them to the conclusion that domestic firms benefit from technology transfer through foreign direct investment when technological standards are already high enough to accept the stimulus. On the other hand, they point to the risk of destroying weak domestic technology resources through knowledge inflows via direct investment by foreign enterprises, which can prove to be a 'Trojan horse'.[6]

In case studies dealing with the mid-seventies, Mansfield discovered that new technologies developed in the United States were primarily transferred abroad via affiliates and to a far lower degree through the export of goods and services (case 1). Mansfield also examined case 3, technology transferred by American affiliates to their parent companies in the United States ('reverse' technology transfer). Forty per cent of R&D expenditure by 29 foreign research units of American enterprises from various industries produced technological results that were transferred to the United States. The time lag between introduction of the technologies outside the United States and their introduction in America was on

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[5] Berthold (1992), p. 51.

[6] Cantwell and Dunning (1991).

average very brief. With the aid of an econometric model to determine total factor productivity for fifteen multinational enterprises in the chemical and oil-refining industries between 1960 to 1976, in which R&D capital stocks were taken into account separately for home and abroad, Mansfield showed that research outside the country had a positive impact on the development of productivity in the American companies.[7] The authors are reserved in evaluating the findings of these still isolated analyses of the links between international technology transfer and technological competitiveness.[8]

On the question whether direct investments enhance the competitiveness of parent companies' home countries or that of affiliates' host countries, Dunning comes to the conclusion: 'It all depends.'[9] It is inferred from the growing cross-border mobility of resources that the ability of countries to create attractive locational conditions for the production of intermediate inputs and services (including those to which R&D give rise) is becoming more and more important for national competitiveness.[10]

The phenomenon of increasing international intercompany knowledge flows in multinationals is a relatively new challenge for economic research into the relations between technical development, corporate competitiveness, and regional performance. An additional problem is posed by the economic estimation of the knowledge stocks of businesses and locations, and the knowledge flows moving among them.

**Problems in measuring and estimating stocks and flows of knowledge in group companies**

In order to analyse the influence of the continuously renewed stock of knowledge on the development of productivity and income, this stock of knowledge has to be appraised economically. This has hitherto been attempted in analogy to the valuation of fixed assets. However, whereas individual physical assets (buildings or equipment) are freely traded on the market, where their price is determined by competition, this applies to knowledge only in a limited respect, namely to the R&D that companies offer on the market; to the rights of use in technical knowledge (patents and licences); and to the knowledge embodied in research instruments, equipment, and intermediate inputs. The labour market determines the price of R&D labour. The situation is different with respect to

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[7] Mansfield (1987)

[8] Mansfield (1987)

[9] Dunning (1992), p. 165.

[10] Levy and Dunning (1993).

knowledge held exclusively within the business or group and transferred only via intra-firm knowledge flows between member companies. This intra-company knowledge is not exchanged and priced on the market. Because of the differing valuation criteria, expenditure on knowledge acquired on the market and expenditure on intra-company knowledge cannot be subsumed under *one* stock of knowledge. Analogies between physical capital stocks (fixed assets) and non-physical R&D capital stocks can be asserted for only part of the knowledge exchanged on the market. There are two reasons:

(1) Knowledge is partly mobile, i.e. the place where it originates and the place(s) where it finds application (*utilization*) can diverge;

and

(2) A larger proportion of the exchange of knowledge than of the exchange of physical assets (where only self-produced items are concerned) occurs outside the markets, giving rise to estimation problems on the *supply side.*

The growing globalization of knowledge flows — within multinational corporations, through international joint ventures and strategic alliances — gives businesses access to stocks of knowledge in other countries. These flows of knowledge fail in part to be reflected in the balance of payments, or, where they are, intra-firm, criteria are used, which differ from market valuation criteria for the estimation of knowledge.[11] In estimating national knowledge resources, an attempt should therefore be made to segment it so as to show differential public availability and/or merchantability of the knowledge concerned.

Crucial to a company's technological competitiveness is the exclusiveness of the knowledge available within the business. With respect to both the technical knowledge developed by the company and acquired knowledge, a distinction must be drawn between:

- Generally available, merchantable knowledge;
- Knowledge available in a limited number of different businesses (joint ventures, strategic alliances);

  and
- Exclusive knowledge available only within a group of companies.

[11] Cross-border transfers between group companies should be assessed in accordance with the arms-length principle. Calculation of transfer prices is often controversial. Governments fear that multinational enterprises manipulate these prices to save taxes by lowering reported profits. See Business Week (1994), p. 23.

In assessing locational performance, a distinction is drawn between regionally immobile and mobile knowledge. With regard to the geographical diffusion of knowledge, Krugman hence distinguishes three components:

- Knowledge internalized only in resident firms;
- Knowledge that is mobile between various businesses, but which does not cross regional/-national frontiers. Such knowledge triggers local externalities;
- And knowledge that is available interregionally/internationally.[12]

It is therefore necessary to distinguish the components of R&D capital stocks:

- Regionally by location of origin and location of utilization;
- Economically by the form of exchange/acquisition on markets, through forms of corporate cooperation, and between group companies.

In addition to other forms of R&D cooperation, the expansion of R&D networks within multinational corporations is growing in importance. This can be demonstrated quantitatively by taking the example of the United States, where research expenditure by foreign affiliates in America and American affiliates abroad are recorded in the statistics on direct investment. The share of R&D expenditure by foreign affiliates in total R&D expenditure by industry within the country grew from just under 5 per cent in 1977 to a good 15 per cent in 1991. In 1991, spending on research by American affiliates abroad expressed in dollars corresponded to a good 12 per cent of total R&D expenditure by industry in the United States. R&D spending by foreign firms in America was thus higher than R&D expenditure by American affiliates outside the United States. Average R&D turnover intensity in foreign manufacturing affiliates in the United States in 1991 was 78 per cent of that of all companies in the country. This gap has not appreciably altered in the past decade. The average R&D turnover intensity in foreign affiliates grew just as it did in all manufacturing companies in the United States. There were, however, differences between industries. Since the beginning of the eighties, the real growth rates of R&D spending by European and Japanese affiliates in the United States have been higher than real growth rates in turnover.[13]

In assessing the technological competitiveness of the Federal Republic of Germany, we must first determine how German and foreign companies in the country are tied into these R&D networks. The

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[12] Krugman (1987).

[13] Dunning and Narula (1994)

aim is to provide answers to questions such as the following: Taking into account the knowledge flows within multinational corporations, how does the share of knowledge generated abroad develop in relation to the knowledge utilized within the country and vice versa? What impacts are to be expected from the progressive international division of labour among group companies with regard to the future technological performance of the national economy?

Since the corporate data recorded in terms of the ownership principle that is required for such investigations are not available for Germany, we will show in the coming sections how this problem can nevertheless be addressed with the aid of existing statistics and company surveys.

## 3 The international networking of industrial enterprises

Bundesbank statistics on external financial interrelations can reveal the international linkage of multinational corporations for the Federal Republic of Germany. These statistics record both businesses abroad with a balance sheet total exceeding DM 0.5 million owned directly or indirectly (through participation of a foreign company in further companies) by domestic firms or private persons holding more than 20 per cent of the shares or voting rights, and businesses in Germany in which foreigners hold more than 20 per cent of the shares or voting rights. In simple terms, one could speak of German affiliates abroad and foreign affiliates in Germany. Data on the number of affiliates, turnover, employment, and balance sheet totals are available for these businesses. We thus obtain information on the interlinkage of businesses within and outside the country providing the framework for the technological interpenetration of group companies.

### The technological interdependence of domestic and foreign companies

German affiliates abroad can be assigned to the sector to which the investing enterprise in Germany belongs and to the sector of the investment project abroad. Approximately one third of total direct and indirect investment abroad, which in 1991 amounted to DM 260 billion, flowed from domestic manufacturing companies to manufacturing businesses abroad. This also approximates the technological-related share of German investment abroad, since investment by German industries in foreign industrial firms is presumably dominated by links and knowledge flows relating to manufacturing technology. Moreover, The participation of industrial enterprises in trading companies (12 per cent of all direct and indirect investment abroad) and vice versa (1 per cent) is partly connected with flows of technical knowledge in both directions. Of direct foreign investment by

German companies in the manufacturing sector, totalling DM 136 billion in 1991, 63 per cent went to industrial firms and 22 per cent to trading companies, the remainder going to equity investment companies, banks, insurance companies, etc. Direct investments form the framework for analysing linkage-related knowledge flows among company locations and the R&D specialization developing among them.

**Regional networking**

Businesses in the Federal Republic of Germany invest predominantly in developed Western industrial countries. Of the total direct investments by domestic companies abroad in 1991, 51 per cent went to EC countries and 23 per cent to the United States. Technological-related interlinkage between businesses at home and abroad also concentrated on the leading industrial countries. In regard to direct investments by domestic manufacturers in manufacturing abroad, the share of EC countries was 42 per cent and that of the United States 28 per cent. In foreign direct and indirect investments in the German manufacturing industry in 1991, investors from EC countries held a 42 per cent share and the United States 27 per cent. This strong technology component in the financial interrelations between leading technology countries of the Triad cast doubt on the thesis that the technology producing countries, which are also technology users, are prime victims of the technology outflow towards less developed countries. It is more likely that the competitive position and the performance of corporate locations will be much more strongly affected by international specialization in production and sales, and, increasingly, in research and development among group companies in the developed industrial regions.

**The types of foreign investment undertaken by German businesses**

To determine the type and extent of holdings, 821 recorded transactions by 350 West German businesses in the period between 1985 and 1989 have been examined.[14] Slightly fewer than three quarters of these transactions involved acquiring established firms by obtaining a 25 to 100 per cent interest. Over half the acquisitions were full takeovers. New businesses, a good quarter of the total, played a far less significant part in growth abroad. They were generally set up with the participation of another company. 84 per cent of the acquired or newly established foreign affiliates were in developed Western industrial countries (Europe, North America, Japan). The predominance of takeovers over new business starts, which is particularly marked in the developed industrial regions,

[14] FAST 1990.

reflects the fact that, in order to strengthen their competitive position, German companies abroad prefer to exploit existing potentials for production, market entry, integration into supplier networks, etc., as well as existing knowledge resources. Issues that must be addressed are whether they further develop these knowledge resources, what ramifications such developments have for Germany as a technology location, and whether foreign companies investing in Germany behave in a similar manner to Germans abroad.

**Indicators of the international networking of domestic companies**

Corporate data in an ownership-based framework are needed to measure the degree of interlinkage between German businesses and foreign firms and to permit inferences to be drawn on the behaviour and competitiveness of multinational corporations and of group and free-standing national firms.[15] Such data are not yet available for the Federal Republic of Germany. However, at least some of the pertinent information can be obtained from location-related statistics. If one brings together corporate data from the statistics on financial interrelations with abroad and corresponding data on domestic companies from the Federal Statistical Office cost-structure statistics on manufacturing industry, the following business categories can be derived:

- Domestic companies in Germany, of which
  - * German companies in Germany;
  - * Foreign affiliates in Germany;

and

- All German companies, of which
  - * German companies in Germany;
  - * German affiliates abroad.

For each of these categories, the number of firms, annual turnover, and employment in the Federal Republic of Germany (within the borders prior to 3 October 1990) were calculated by industry for the period from 1977 to 1991.[16] The companies in other countries recorded in the statistics on financial interrelations are assumed to be essentially affiliates of German multinational corporations abroad, and

[15] In the United States, data on multinational corporations are recorded in the direct investment statistics of the United States Department of Commerce separately for American parent companies, American affiliates abroad, and foreign affiliates in the United States.

[16] In late 1991, DM 2.5 billion of German direct investments abroad were made by investors resident in the new federal states (about 1 per cent); the stake of foreigners in East Germany in the same period was almost as high (also about 1 per cent) (Deutsche Bundesbank [1993], p. 34).

the companies recorded in Germany to be affiliates of foreign multinationals. However, it is not possible in this manner to obtain information on the parent companies and on further companies in the group located in Germany, since, like free-standing firms in the Federal Republic, they are assigned to the category of German companies in Germany.

Table 1 shows that the ratio of foreign affiliates to all domestic companies in the manufacturing industry did not change over the 1977 - 1991 period, both in regard to employment, with about 17 per cent of the domestic labour force, and turnover, with a quarter of the total turnover of domestic businesses. However, industries differ considerably in their share of foreign companies in Germany and in development trends. In 1991, more that half the turnover of all domestic companies in Germany in tobacco products and oil refining was earned by foreign firms. Foreign companies also had a large share of domestic turnover in the chemical industry, in non-ferrous metals, in rubber products, and in precision and optical instruments, watches and clocks. In the large, research-intensive industries road vehicles and electrical engineering, the share in turnover earned by foreign firms was just under a quarter.

Table 2 shows the figures calculated according to the method described above on the shares of German affiliates abroad in employment and turnover of all German companies throughout the world (ownership-based framework). In manufacturing industry, both shares grew considerably in the period from 1977 to 1991. German investors showed an increasing interest, particularly from the second half of the eighties, in acquiring holdings and firms abroad. In 1991, industries exhibiting especially high international networking of German companies were the chemical industry and aerospace, each of which earned half of total turnover in foreign affiliates. With over a quarter of total turnover abroad, German companies in the rubber products, electrical engineering and road vehicles industries also had a high degree of foreign linkage. This list alone reveals the similarity of sectoral structures between foreign affiliates in Germany and German affiliates abroad. The similarity is also apparent when the turnover of these affiliates in Germany and abroad in the most important industries is compared (Figure 2).

## 4 R&D flows in multinational corporations

To the extent that cross-border flows of R&D services are recorded in the Federal Republic of Germany by the Stifterverband (SV-Wissenschaftsstatistik GmbH) and the Deutsche Bundesbank, it is not clearly apparent how far these flows occur between companies within groups. Nevertheless,

Table 1

Share of Foreign Affiliates in Domestic Firms
in the Federal Republic of Germany
in %

| Sectors | Employment | | Turnover | |
|---|---|---|---|---|
| | 1977 | 1991 | 1977 | 1991 |
| Manufacturing | 17.1 | 16.2 | 25.2 | 25.3 |
| Chemical products | 22.1 | 32.7 | 25.0 | 39.9 |
| Oil refining | 72.3 | 43.9 | 91.5 | 66.0 |
| Plastic products | 15.8 | 15.3 | 20.1 | 20.2 |
| Rubber products | 33.8 | 24.1 | 43.9 | 32.1 |
| Quarrying | 14.6 | 16.4 | 18.9 | 16.7 |
| Ceramic and glass products | 25.4 | 19.0 | 35.2 | 24.0 |
| Iron and steel | 40.5 | 20.6 | 36.5 | 21.0 |
| Foundries | 5.8 | 10.7 | 6.7 | 11.3 |
| Drawing mills, cold rolling mills | 8.2 | 7.6 | 10.0 | 10.5 |
| Non-ferrous metals | 18.9 | 24.6 | 22.9 | 36.0 |
| Structural metal products | 12.1 | 4.0 | 11.2 | 5.1 |
| Mechanical engineering | 16.7 | 13.3 | 19.8 | 15.7 |
| Road vehicles | 21.7 | 17.2 | 24.3 | 21.6 |
| Aircraft and spacecraft | 52.4 | 9.8 | 62.7 | 24.8 |
| Electrical engineering | 21.3 | 17.2 | 29.3 | 23.5 |
| Precision and optical instruments, watches and clocks | 16.3 | 21.1 | 21.2 | 28.7 |
| Tools, finished metal products | 12.8 | 12.1 | 16.2 | 16.0 |
| Musical instruments | 6.7 | 4.6 | 9.7 | 7.6 |
| Saw mills and timber processing | 4.4 | 5.5 | 4.6 | 5.2 |
| Wood processing | 1.3 | 2.7 | 1.2 | 3.1 |
| Pulp and paper processing | 7.6 | 24.3 | 9.1 | 22.8 |
| Paper and board products | 13.7 | 20.0 | 17.7 | 25.9 |
| Printing and publishing | 2.2 | 1.1 | 4.4 | 1.6 |
| Leather and leather products | 2.1 | 8.3 | 1.5 | 20.5 |
| Textiles | 8.6 | 10.2 | 9.9 | 12.5 |
| Wearing apparel | 1.9 | 3.1 | 2.7 | 6.5 |
| Food | 14.8 | 14.9 | 17.8 | 21.3 |
| Tobacco | 54.7 | 74.4 | 65.5 | 78.7 |
| Other industries | 4.1 | 34.4 | 4.8 | 50.9 |

Sources: Statistisches Bundesamt; Deutsche Bundesbank; DIW calculations.

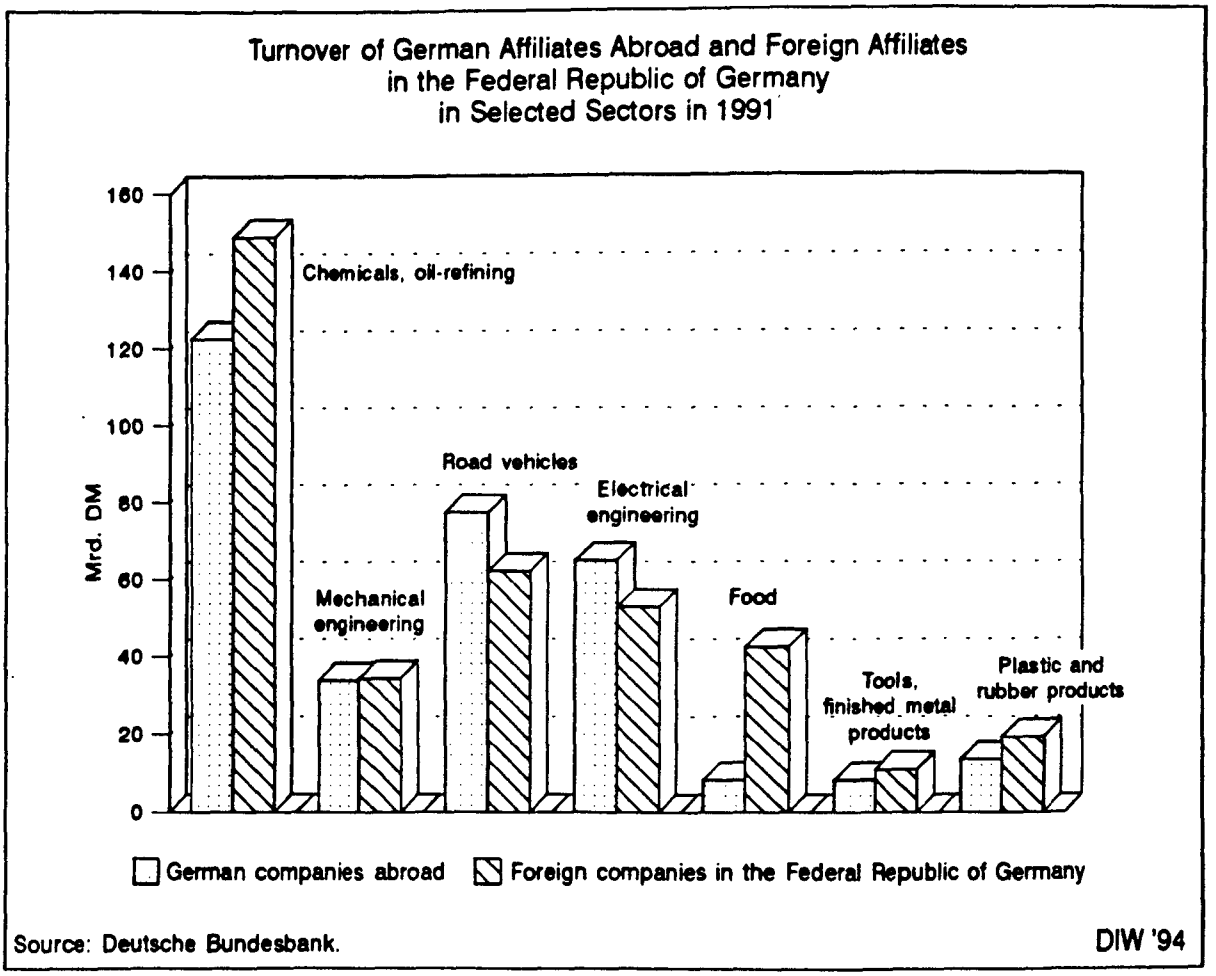
## Table 2

### Share of German Affiliates Abroad in German Companies World-wide in %

| Sectors | Employment | | Turnover | |
|---|---|---|---|---|
| | 1977 | 1991 | 1977 | 1991 |
| Manufacturing | 13.6 | 20.8 | 12.9 | 21.3 |
| Chemical products | 30.0 | 46.9 | 27.6 | 50.5 |
| Oil refining | 9.4 | 6.6 | 19.3 | 1.4 |
| Plastic products | 8.3 | 9.3 | 10.0 | 10.9 |
| Rubber products | 12.6 | 30.5 | 8.8 | 34.2 |
| Quarrying | 7.3 | 15.3 | 7.8 | 14.2 |
| Ceramic and glass products | 12.3 | 14.0 | 10.8 | 16.0 |
| Iron and steel | 18.4 | 14.4 | 16.5 | 8.6 |
| Foundries | 5.8 | 19.3 | 4.1 | 15.7 |
| Drawing mills, cold rolling mills | 8.7 | 12.9 | 8.5 | 13.3 |
| Non-ferrous metals | 2.4 | 10.1 | 1.4 | 12.7 |
| Structural metal products | 10.6 | 11.2 | 5.2 | 9.9 |
| Mechanical engineering | 10.4 | 15.4 | 10.5 | 15.5 |
| Road vehicles | 23.6 | 31.1 | 18.7 | 25.5 |
| Aircraft and spacecraft | 25.1 | 4.5 | 38.0 | 49.5 |
| Electrical engineering | 19.0 | 27.0 | 20.5 | 27.4 |
| Precision and optical instruments, watches and clocks | 14.2 | 17.1 | 16.2 | 19.5 |
| Tools, finished metal products | 8.7 | 11.6 | 7.4 | 12.6 |
| Musical instruments | 6.7 | 7.4 | 13.1 | 13.3 |
| Saw mills and timber processing | 10.2 | 17.0 | 3.1 | 7.1 |
| Wood processing | 2.5 | 7.0 | 2.1 | 4.1 |
| Pulp and paper processing | 9.3 | 22.8 | 11.1 | 21.2 |
| Paper and board products | 4.7 | 3.7 | 5.6 | 6.0 |
| Printing and publishing | 2.8 | 2.1 | 3.0 | 2.5 |
| Leather and leather products | 9.8 | 31.3 | 9.9 | 20.5 |
| Textiles | 7.5 | 16.3 | 6.5 | 14.0 |
| Wearing apparel | 8.6 | 16.6 | 4.3 | 6.5 |
| Food | 3.9 | 5.4 | 2.6 | 5.0 |
| Tobacco | 34.1 | 62.8 | 12.6 | 24.1 |
| Other industries | 1.4 | 10.9 | 0.6 | 9.2 |

Sources: Statistisches Bundesamt; Deutsche Bundesbank; DIW calculations.

Figure 2


Turnover of German Affiliates Abroad and Foreign Affiliates
in the Federal Republic of Germany
in Selected Sectors in 1991
Mrd. DM
160
140
120
100
80
60
40
20
0
Chemicals, oil-refining
Road vehicles
Electrical engineering
Mechanical engineering
Food
Tools, finished metal products
Plastic and rubber products
German companies abroad
Foreign companies in the Federal Republic of Germany
Source: Deutsche Bundesbank.
DIW '94

these statistics will be briefly discussed here, so that the starting point for expanding them to record intra-group flows can be addressed.

R&D expenditure in German industry is recorded at two-year intervals by the Stifterverband by means of company surveys. Cross-border research transfers are recorded separately by execution and financing as 'external R&D contracts' to recipients abroad and as 'R&D expenditure financed from abroad' within the country. The OECD recommends separate reporting of funding of significant dimensions flowing between group companies,[17] but the Stifterverband has yet to put this into practice. It is thus impossible to determine the extent to which this external R&D expenditure flowing abroad includes intra-group funding of group-company contract-research. More-over, the Stifterverband also reports international organizations within the Federal Republic of Germany as being abroad. Between 1979 and 1989, the extent of external R&D expenditure by manufacturing industry abroad has nominally increased sevenfold. There are sectoral differences. The chemical industry set the pace with a sevenfold rise in spending, while external expenditure abroad by mechanical engineering only tripled, and in the second half of the eighties even fell. For external R&D payments flowing abroad by German companies in the manufacturing industry, the Stifterverband reports a total of DM 748 million for 1989. This is equivalent to 1.6 per cent of total domestic R&D expenditure. The share of the chemical industry is 2 per cent, the automotive industry 1.1 per cent, and mechanical engineering 0.6 per cent. R&D spending in manufacturing industry financed from abroad showed a nominal growth to only 270 per cent over the 1979 - 1989 period, thus growing more slowly than external R&D expenditure outside the country. At DM 1.4 billion in 1989 this figure was, however, approximately twice as high as external R&D payments flowing abroad. At 2.9 per cent, the share of total R&D spending financed from abroad was also relatively small.

In the balance of payments statistics for the Federal Republic of Germany, the Deutsche Bundesbank reports company payments and receipts relating to technological services — including patents and licences — as well as to research and development. According to the Bundesbank, payments flow for the most part between group companies. Referring to the type of transactions involved, The Bank states: 'Whereas in patent and licence transactions payments flow predominantly from the respective affiliates to the parent companies, payments in the field of research and development flow mostly in the opposite direction, i.e. from the parent companies to affiliates. In certain fields, such as the

[17] Federal Ministry of Research and Technology (BMFT) 1982.

computer and the automotive industries, by contrast, the exchange of technology between domestic and foreign sister companies of foreign groups is also playing an increasingly important role.'[18]

In 1993 payments for R&D services in manufacturing industry attained a value of DM 3.7 billion. Receipts, by contrast, amounted to DM 2.9 billion. Whereas expenditure on R&D services in the 1979 -1993 period grew eightfold, income grew only four-and-a-half-fold. In 1992 expenditure was for the first time higher than income (Figure 3). Since, according to the Bundesbank, payments for R&D services usually flow from the parent companies to affiliates, the more rapid rise in expenditure in recent years points to the growing foreign interests of German companies and to the increasing knowledge flows from German affiliates abroad to parent companies at home. The regional distribution of R&D-related expenditure and revenue shows a high concentration of payments in Europe and the United States as both user and producer regions. Comparing the Stifterverband data on external payments flowing abroad and Bundesbank statistics on spending on R&D by the mechanical engineering industry shows that until the mid-eighties the amounts matched with a two-year lead time for R&D spending before payments. For other industries there is a similar lead time for the figures in both surveys. This is an indication that both the Stifterverband data on external R&D expenditure abroad and the Bundesbank data on spending on R&D abroad relate primarily to R&D flows within multinational corporations.

The OECD is seeking to improve and in the long run to harmonize the collection of data on the technological balance of payments.[19] However, fundamental problems are perceived that could limit the usefulness of such balances:

(1) The monetary evaluation of knowledge transfer between group companies depends on intra-group pricing;

(2) Payments for technical knowledge cannot always be unequivocally identified;

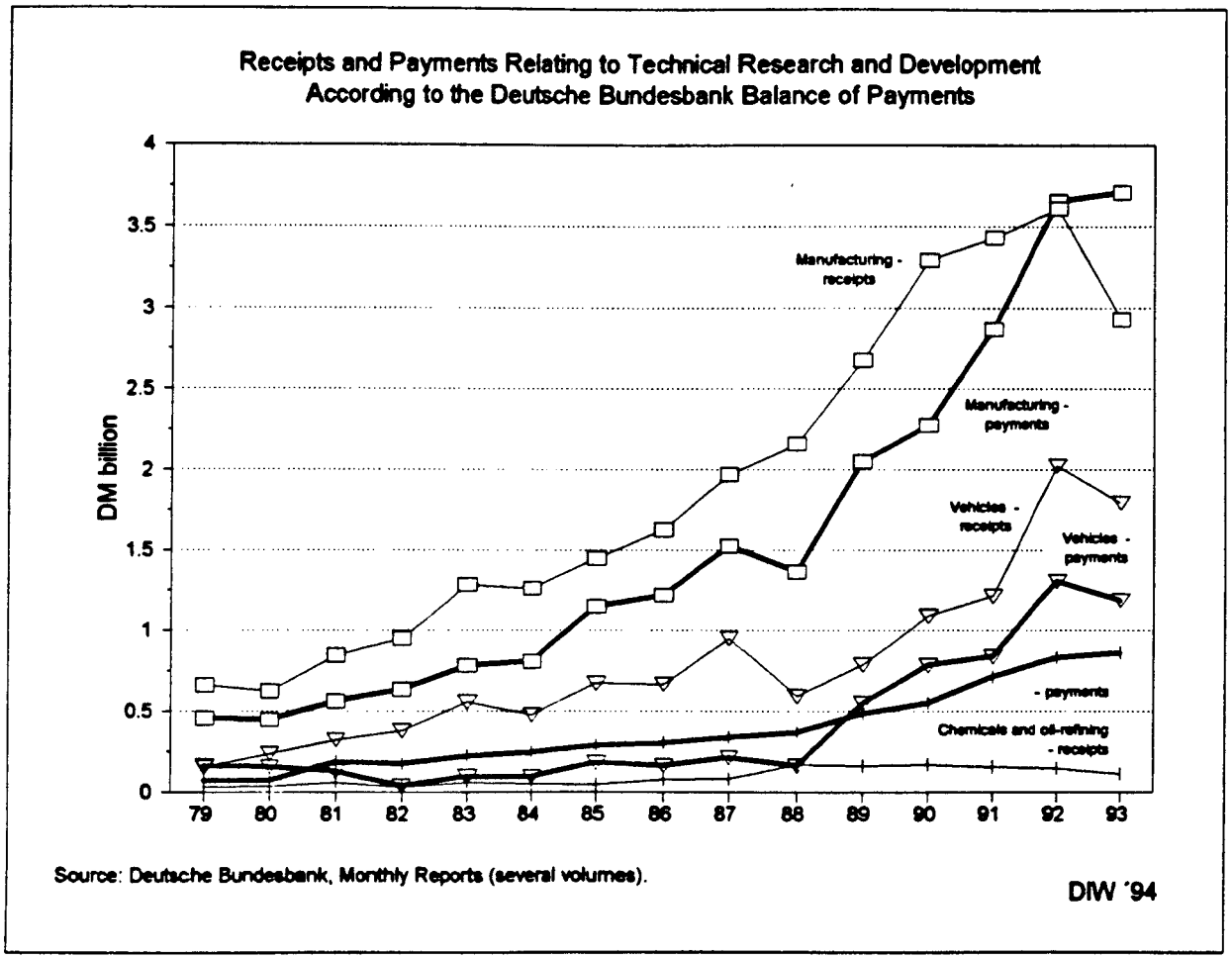
(3) Knowledge transfer does not always relate to a specific financial transfer.

In view of the fundamental discussion on the estimation of knowledge flows (section 1) and the practical problems involved in recording cross-border knowledge flows, it is clear that these flows of funds — although predominantly attributable to intra-group knowledge flows — are not a suitable

[18] Deutsche Bundesbank (1992), p. 35.

[19] OECD (1990).

**Figure 3**


Receipts and Payments Relating to Technical Research and Development
According to the Deutsche Bundesbank Balance of Payments
DM billion
4
3.5
3
2.5
2
1.5
1
0.5
0
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
Manufacturing - receipts
Manufacturing - payments
Vehicles - receipts
Vehicles - payments
- payments
Chemicals and oil-refining - receipts
Source: Deutsche Bundesbank, Monthly Reports (several volumes).
DIW '94

instrument to indicate changes occurring in international specialization in the research and development conducted by multinational corporations.

**The industry-specific intensity of intra-group knowledge flows**

In assessing the differential importance of intra-group knowledge flows in the various industries, and thus the differential mobility of knowledge within industrial groups, recourse has been taken to the 1987 Federal Statistical Office test survey of services in manufacturing industry.[20] The survey data permits the offer and purchasing of R&D services in manufacturing industries to be analysed by source — own firm, group, and free-standing firm. However, it is not possible to distinguish between cross-border and domestic flows.

There is high intra-group mobility of technical knowledge where companies can acquire large quantities of knowledge from geographically remote group companies. The test survey permits the proportion of businesses in the industry to be determined that offer R&D services and of those that procure R&D services from a range of sources. Sources can be classified as:

- Procurement exclusively from own company;
- Procurement exclusively from within the group (industrial group and own company); and
- Purchasing also from outside firms (Table 3).

The study looks only at industries with a research-staff intensity of over 1 per cent (measured as the ratio of R&D staff to total workforce).

The proportion of companies in each industry that offer R&D services rises with the research intensity in the industry ($R^2$=0.6 for 18 industries). There is no relation between the proportion of companies in an industry that offer R&D services and the proportion of companies that purchase such services. On the basis of these data it was therefore not possible to ascertain whether a high proportion of firms offering R&D services is matched by a low proportion of firms acquiring R&D services.

However, marked industry-specific differentials are apparent in the significance of intra-group knowledge flows and group companies as sources of technological knowledge (R&D services). The proportion of companies procuring knowledge predominantly from other firms in the group (less those using knowledge emanating exclusively from within the company) is relatively high in some industries

[20] Statistisches Bundesamt, Dienstleistungen im Produzierenden Gewerbe, Fachserie 4, Reihe p.12, 1988.

## Table 3

## Offer and Procurement of R&D Services in Manufacturing 1987

| Sector | for information: R&D intensity[1] | Share of companies with | | | | |
|---|---|---|---|---|---|---|
| | | Offer of R&D services | Consumption of R&D services | R&D procured | | |
| | | | | exclusivly in-house | from group companies and in-house | also from free standing companies |
| | in % | in % | in % | in % | in % | in % |
| Mobile Industries | | | | | | |
| Oil refining | 4.2 | 14.3 | 76.2 | 33.4 | 19.1 | 23.9 |
| Rubber products | 2.1 | 20.3 | 89.1 | 51.6 | 20.3 | 17.2 |
| Office machines, data processing equipment | 9.7 | 23.3 | 90.0 | 56.7 | 20.0 | 13.3 |
| Chemical products | 9.8 | 17.2 | 90.1 | 47.8 | 21.6 | 20.7 |
| Non-ferrous metals | 1.2 | 7.1 | 72.9 | 37.2 | 17.1 | 18.6 |
| Glass products | 1.5 | 9.5 | 71.4 | 34.9 | 17.4 | 19.1 |
| Aircraft and spacecraft | 24.4 | 28.6 | 85.7 | 61.9 | 14.3 | 9.5 |
| Average | 7.6 | 17.2 | 82.2 | 46.2 | 18.5 | 17.5 |
| Immobile Industries | | | | | | |
| Quarrying | 2.2 | 5.8 | 73.3 | 44.2 | 9.3 | 19.8 |
| Road vehicles | 4.9 | 15.9 | 65.4 | 43.4 | 6.1 | 15.9 |
| Electrical engineering | 7.7 | 17.4 | 84.4 | 52.8 | 10.2 | 21.4 |
| Shipbuilding | 1.5 | 15.4 | 69.2 | 46.2 | 2.6 | 20.5 |
| Mechanical engineering | 3.6 | 14.1 | 84.9 | 58.4 | 6.4 | 20.3 |
| Finished metal products | 1.5 | 7.7 | 78.1 | 53.7 | 6.2 | 18.2 |
| Structural metal products | 1.4 | 12.5 | 64.0 | 46.3 | 2.2 | 15.4 |
| Plastic products | 1.4 | 12.7 | 74.1 | 48.2 | 9.6 | 16.4 |
| Precision and optical instruments, watches and clocks | 3.8 | 17.1 | 75.2 | 37.2 | 6.2 | 31.8 |
| Average | 3.1 | 13.2 | 74.3 | 47.8 | 6.5 | 20.0 |

1) Ratio of R&D staff to total workforce 1989.
Sources: SV-Wissenschaftsstatistik; ISI/NIW; Statistisches Bundesamt; DIW calculations.

(for example in the chemical industry; office and computing machinery; rubber products; oil refining). In these industries great use is accordingly made of mobile knowledge acquired from group companies. In other industries knowledge procurement from within the group plays a much less significant role (mechanical engineering, shipbuilding; precision and optical instruments, watches & clocks; road vehicles). In terms of this criterion, industries were classified as mobile industries where between 14 per cent and 22 per cent of firms purchase knowledge from companies in the group, and immobile industries where the proportion is between 2 per cent and 10 per cent. On average there is hardly any difference between the two groups with respect to the importance of intra-company knowledge (proportion of firms for the most part using knowledge from within the company) and extra-group knowledge, largely acquired on the market (proportion of companies that also purchase R&D services from free-standing firms).

This rough classification of entire industries in terms of the type of knowledge transfer within group companies should not blind one to the fact that there are technological areas in mobile industries that have largely immobile knowledge and vice versa. Thus the relatively high proportion of companies in electrical engineering, classified here as a largely immobile industry, that purchase knowledge from within their group points to areas of business and technology with mobile knowledge.

## 5 R&D resources in multinational corporations

According to the concept of technological location potential advocated in this paper, the technological efficiency of a location depends essentially on the possibilities for access by the resident company to the R&D resources available to it throughout the world. This access potential is only partly reflected by actual knowledge flows. For one thing, knowledge flowing between group companies (section 4) can be depicted only very incompletely through the recordable flows of funds, and for another, indicators of technological competitiveness are intended to show not only actual knowledge but also the potency and capacity of the knowledge sources — the research units in group companies — for providing knowledge in vital fields of technology in the future. Qualitative and quantitative information on the research units of group companies abroad is needed for this purpose.

### Classification of R&D units in group companies

Research units in multinational corporations are assigned different tasks in intra-group specialization in research and development. To some extent, research activities are closely tied in with production

at the site concerned, and to some extent they are independent of local production. A number of authors have proposed comparable classifications of R&D units in group companies (Table 4). Whereas production-related R&D units are of prime importance in enhancing local competitiveness, the results achieved by R&D units unrelated to local production are also available to member companies of the group located elsewhere.

In Ronstadt's classification[21], technology transfer units (TTU) are closest to production. To transfer the technology of the parent company to affiliates abroad, technical support is frequently required on the spot. Customers may, moreover, expect the provision of technical servicing, which has to be supplied by local R&D staff. In the support laboratories, additional adaptation of products to local market conditions is carried out. The indigenous technology unit (ITU) develops own products for the local market. This is often characteristic of takeovers of a firm operating locally. Local product development facilitates, or permits, the successful entry by foreign companies into differentiated and demanding markets.

Like technology-support R&D activities, locally integrated R&D often depends on parent-company technology. It is, however, fully adapted to local conditions. The internationally independent laboratories (IIL) have a global rather than local orientation, and are little involved in local production. They are intended to investigate or develop new technologies, for which the highly-qualified research staff can (only) be obtained abroad (corporate technology units[CTU]).

It is a strategy of large multinational corporations such as IBM to develop a product for simultaneous introduction on the most important markets. The R&D units existing in all large regional markets (global technology units [GTU]) must therefore cooperate closely.

There are few studies on the quality of research conducted abroad by German multinationals. They relate to selected companies and cases. The location portfolio of the multinational Bayer shows that this enterprise also conducts basic research abroad that does not tie in with local production (Figure 4).

[21] Ronstadt (1977).

**Table 4**

CLASSIFICATION OF R&D UNITS OF GROUP COMPANIES IN TERMS OF RELATION TO LOCAL PRODUCTION[22]

| Authors of classification | | | |
|---|---|---|---|
| **Cordell (1973)** | **Ronstadt (1977)** | **Pearce (1989)** | **Hakanson/Nobel (1993)** |
| Support Laboratories (SL) | Technology Transfer Units (TTU) | Support Laboratories (SL) | Production Support Units |
| | Indigenous Technology Units (ITU) | | |
| | Global Technology Units (GTU) | Locally integrated Laboratories (LIL) | Market Oriented Units |
| International Independent Laboratories (IIL) | Corporate Technology Units (CTU) | International Independent Laboratories (IIL) | Research Units |

**Quantifying the R&D resources of multinational corporations abroad**

Table 5 gives an overview of important studies on recording the R&D resources of multinational enterprises abroad. The majority of these studies are concerned with the R&D resources of affiliates abroad from the perspective of the home country of the parent company. Only very recently has the influence of research and development by foreign affiliates on the host country become an object of investigation.[23] In the following section, we will attempt to assess the R&D resources of the domestic chemical industry abroad with regard to the Federal Republic of Germany.

**Research and development by the German chemical industry abroad**

In German manufacturing, the chemical industry has the highest direct investments abroad and is the industry most closely interlocked with companies in other countries. Not only is a high proportion — almost one fifth — of total domestic expenditure on R&D ascribable to firms in the chemical industry, this sector also has the largest share in research by affiliates abroad.

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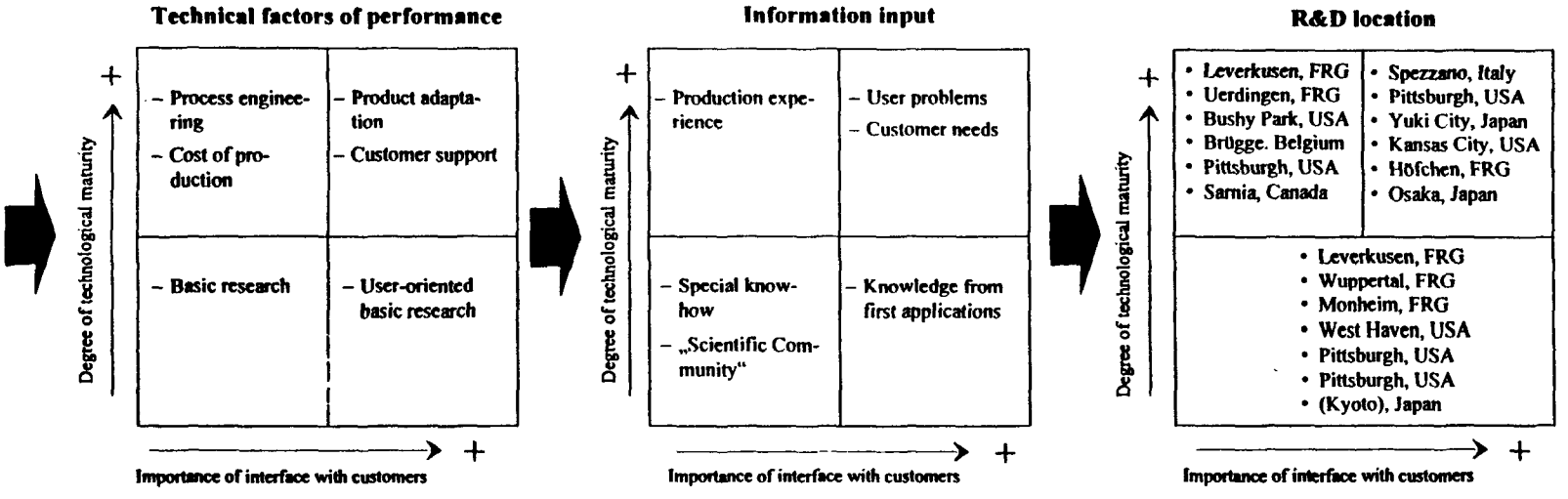
[22] Vgl. Pearson, Brockhoff und Boehmer (1993).

[23] Dunning and Narula (1994).

Figure 4

## Research and Development Sites of the Chemical Concern Bayer




Source: Fürstenwerth (1993).

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Spending by the chemical industry on research is concentrated in the three groups Bayer, Hoechst and BASF, which together spent 60 per cent of the money invested in R&D in the industry as reported by the Stifterverband. Hoechst and Bayer have the largest share in research and development by affiliates abroad. They are the outstanding German actors abroad in the development of markets and technologies. Hoechst has research facilities in fifteen countries, among which product and technology-related research, particularly in pharmaceuticals, are distributed. Hoechst began conducting research abroad in the late sixties, and this activity has grown with the international business of the firm. Partly consequent on big takeovers in the seventies and eighties, the share of R&D expenditure by foreign affiliates of the Hoechst group grew to 40 per cent by the end of the eighties. Bayer, too, has been fostering the realization of a global research strategy with internationally specialized R&D structures. The share of research spending abroad rose to about one third of total outlay for R&D. In both multinationals, the orientation of international research on the 'cornerstones of the Triad', the United States, Europe, and Japan, is clear (Table 6). The pharmaceuticals industry conducts a higher proportion of research abroad than at home.

In total, the share of R&D spending abroad in global R&D expenditure by the three large groups Bayer, Hoechst, and BASF grew from 7 per cent in 1970 to 32 per cent in 1992. In addition to the three large chemical groups, nine further large chemical companies were looked at, which, together with the three mentioned, were responsible in 1992 for about 90 per cent of domestic outlay on R&D by the chemical industry outside the field of pharmaceuticals.[24] In 1992 the twelve largest German chemical companies spent about DM 1.3 billion on research in fields other than pharmaceuticals in affiliates abroad. The other German companies not reported presumably spent nothing or only small amounts on research abroad. The ratio of R&D expenditure by the German chemical industry abroad to domestic outlay is thus about 1 to 5. Since domestic spending on R&D includes expenditure by affiliates of foreign companies, the share of foreign R&D expenditure of enterprises with their head office in Germany increases. Affiliates of foreign chemical companies in Germany spent an estimated half a billion DM on R&D. The three largest chemical companies spent almost four-fifths of the money invested in research abroad by the German chemical industry.

[24] For reasons, among others, of national licensing of medicines, pharmaceuticals is traditionally the field exhibiting the greatest degree of internationalization in R&D, and the one that has been most thoroughly investigated in Germany as well (see Kümmerle 1993). It has therefore not been included in this study of R&D undertaken by German chemical companies abroad.

**Table 5** **Overview of Studies on Research and Development by Multinational Corporations Abroad**

| Home country | Host country | Authors | Number of businesses | Survey year | Share of R&D expenditure abroad in global corporate R&D expenditure[1] | Share of R&D employment abroad in global R&D corporate employment[2] | Share of R&D expenditure by foreign affiliates in total R&D expenditure in host country |
|---|---|---|---|---|---|---|---|
| FRG | world-wide | Jungnickel, Krägenau, Lefeldt and Holthus (1977) | 15 | 1971 | 9,0 | - | - |
| | | | | 1974 | 10,0 | - | - |
| | | Pausenberger (1982) | 11 | 1979 | - | 15,0 | - |
| | | Oesterheld and Wortmann (1988) | 23 | 1983 | - | 17,0 | - |
| | | | 219 | 1988 | - | 11,0 | - |
| | | Brockhoff and Boehmer (1993) | 33 | 1988 | - | 18,0 | - |
| | | Dörrenbacher and Wortmann (1991) | | | | | |
| Europe | world-wide | Dunning and Pearce (1985) | 122 | 1982 | 18,5 | - | - |
| Sweden | | Hakanson (1981) | 56 | 1978 | 12,0 | - | - |
| Sweden | | Hakanson and Nobel (1993) | 20 | 1980 | 20,6 | - | - |
| | | | 20 | 1987 | 22,8 | 25,0 | - |
| USA | world-wide | Mansfield, Teece and Romeo (1979) | 31 | 1960 | 2,0 | - | - |
| | | | 34 | 1965 | 6,0 | - | - |
| | | | 34 | 1970 | 6,0 | - | - |
| | | | 34 | 1972 | 8,0 | - | - |
| | | | 35 | 1974 | 10,0 | - | - |
| | | | 26 | 1980 | 10,0 | - | - |
| | | Creamer (1976) | ° | 1966 | 6,9 | - | - |
| | | | ° | 1971 | 9,1 | - | - |
| | | | 465 | 1972 | 9,7 | - | - |
| | | | ° | 1973 | 9,3 | - | - |
| | | Dunning and Pearce (1985) | 122 | 1982 | 10,9 | - | - |
| world-wide | USA | Dunning and Narula (1994) on the basis of U.S. Department of Commerce | All foreign affiliates in the USA | 1977 | - | - | 4,8 |
| | | | | 1978 | - | - | 5,6 |
| | | | | 1979 | - | - | 6,2 |
| | | | | 1980 | - | - | 6,4 |
| | | | | 1981 | - | - | 8,8 |
| | | | | 1982 | - | - | 9,3 |
| | | | | 1983 | - | - | 9,3 |
| | | | | 1984 | - | - | 9,2 |
| | | | | 1985 | - | - | 9,2 |
| | | | | 1986 | - | - | 9,7 |
| | | | | 1987 | - | - | 10,6 |
| | | | | 1988 | - | - | 11,3 |
| | | | | 1989 | - | - | 13,2 |
| | | | | 1990 | - | - | 15,8 |
| | | | | 1991 | - | - | 15,5 |

[1] Also covers enterprises that do not carry on research. - [2] Covers only enterprises that carry on research abroad.

The growing holdings of the large German chemical companies abroad, especially in the United States, are frequently interpreted as an expression of the diminishing attractiveness of Germany as a location for research. Whereas some company executives claim that the extension of German companies' research activities to the United States is essentially attributable to the obstacles put in the way of genetic engineering in Germany, others emphasized vis-à-vis the DIW the attractiveness of leading universities and smaller venture capital enterprises in the United States.

Furthermore, research capacity in the large companies in Germany has reached 'the upper critical mass'. Further expansion would incur the risk of producing large-scale, inflexible, centralistic structures, and would hence be economically unwise.[25] Claims that the relocation of R&D capacities is attributable to deteriorating locational conditions for research in Germany are thus relativized. Moreover, spending on R&D in Germany has risen in most chemical companies parallel to spending abroad. Against the background of increasing international specialization, companies act rationally when they not only expand portions of product-related research in their affiliates abroad, but also conduct basic, product-unrelated research in locations where they find the best environment for the

**Table 6**

REGIONAL DISTRIBUTION OF R&D EXPENDITURE AND SHARE OF PHARMACEUTICALS IN THE THREE LARGE CHEMICAL COMPANIES IN 1992

| Enterprise | Share of foreign affiliates in overall R&D expenditure by the enterprise | | | | | Share of R&D expenditure on pharmaceuticals | |
|---|---|---|---|---|---|---|---|
| | Abroad | of which | | | | world-wide | Abroad |
| | | USA | Europe | Japan | Others | | |
| | - in % - | | | | | | |
| Hoechst | 40 | 40 | 50 | 8 | 2 | 47 | 57 |
| Bayer | 35 | 65 | 26 | 9 | 0 | 40 | 68 |
| BASF | 16 | 75 | 19 | 6 | 0 | 15 | 35 |

Source: DIW calculations on the basis of company data.

[25] Fürstenwerth (1991).

given type of research. From the point of view of the technological performance of locations, theexistence of so-called 'centres of excellence', where such basic research is carried out at universities and in predominantly small (affiliated) companies, is to be interpreted as a strength. Apart from the numerous benefits these high-tech islands bring for a location, it is often overlooked that through their affiliates, multinational companies have access to the knowledge generated there, and — after intra-group diffusion — are able to utilize it at other locations. From this perspective, the technological competitiveness of German firms and the performance of the Federal Republic are at risk if German companies do not maintain a presence in the leading technology regions abroad through acquisitions and stakes in outside companies.

In the United States, foreign owners of high technology enterprises are recorded (Table 7). In 1991, 11 per cent of the more than 30,000 firms in the sector were in foreign hands. German industry, with a 1.8 per cent share, ranked third among foreign owners. Only companies from the United Kingdom (2.6 per cent) and Japan (1.9 per cent) were present in greater numbers in the high technology field. In automation and biotechnology, Germany ranked first, and came second to Britain in the field of materials. The relatively heavy investment of German companies in high technology businesses in the United States gives the Federal Republic access to technical knowledge in America.

**The R&D resources of multinationals in the Federal Republic and the United States**

According to the statistics on direct investment issued by the United States Department of Commerce for 1992, American companies spent almost $2.7 billion on research and development in subsidiary companies (i.e. affiliates under the majority control of American shareholders) sited in Germany. This represented a good 7 per cent of total R&D expenditure by the economic sector in the Federal Republic in 1992. German affiliates in the United States spent about $1.9 billion on research and development in 1992 (Table 8). In 1989, R&D spending by affiliates of German and American parents in each other's countries was, at about $1.5 billion in each case, still more or less in balance. There was a remarkable leap in R&D expenditure by American affiliates in the Federal Republic from $1.5 billion in 1989 to $2.5 billion in 1990, largely due to the increase of spending in mechanical engineering and vehicles. This rise cannot be explained alone in terms of rate of exchange fluctuations or the expansion of direct investment — employment in American subsidiaries in Germany grew by 36,000. It is partly a result of growing participation by American affiliates in European computer-industry research consortia.[26] This increase in the late eighties is thus also the expression of growing

[26] Mataloni (1992).

## Table 7

### Capital Holdings of Foreigners in High Technology Sector Companies in den United States, March 1991

| Home country of the company with capital holding | All Sectors | Automation | Biotech-nology | Computer | Materials | Photonics | Software | Telecom-munications |
|---|---|---|---|---|---|---|---|---|
| | - Number of companies - | | | | | | | |
| Total | 30 919 | 3 413 | 974 | 4 541 | 2 302 | 1 673 | 7 095 | 2 424 |
| United States | 27 412 | 3 066 | 868 | 4 212 | 1 957 | 1 471 | 6 887 | 2 182 |
| Abroad | 3 507 | 347 | 106 | 329 | 345 | 202 | 208 | 242 |
| Britain | 813 | 70 | 17 | 56 | 85 | 53 | 73 | 53 |
| Japan | 600 | 66 | 15 | 101 | 42 | 51 | 16 | 66 |
| Germany | 560 | 79 | 20 | 34 | 82 | 36 | 15 | 17 |
| France | 269 | 26 | 6 | 23 | 40 | 12 | 23 | 24 |
| Switzerland | 242 | 28 | 8 | 17 | 23 | 13 | 16 | 6 |
| Canada | 246 | 20 | 4 | 16 | 18 | 9 | 22 | 27 |
| Netherlands | 144 | 5 | 8 | 17 | 23 | 11 | 10 | 12 |
| Sweden | 170 | 21 | 8 | 12 | 10 | 5 | 8 | 6 |
| Taiwan | 35 | 0 | 0 | 10 | 0 | 2 | 1 | 6 |
| South Korea | 22 | 1 | 1 | 6 | 1 | 0 | 1 | 3 |
| | - Structure in % - | | | | | | | |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 88.7 | 89.8 | 89.1 | 92.8 | 85.0 | 87.9 | 97.1 | 90.0 |
| Abroad | 11.3 | 10.2 | 10.9 | 7.2 | 15.0 | 12.1 | 2.9 | 10.0 |
| Britain | 2.6 | 2.1 | 1.7 | 1.2 | 3.7 | 3.2 | 1.0 | 2.2 |
| Japan | 1.9 | 1.9 | 1.5 | 2.2 | 1.8 | 3.0 | 0.2 | 2.7 |
| Germany | 1.8 | 2.3 | 2.1 | 0.7 | 3.6 | 2.2 | 0.2 | 0.7 |
| France | 0.9 | 0.8 | 0.6 | 0.5 | 1.7 | 0.7 | 0.3 | 1.0 |
| Switzerland | 0.8 | 0.8 | 0.8 | 0.4 | 1.0 | 0.8 | 0.2 | 0.2 |
| Canada | 0.8 | 0.6 | 0.4 | 0.4 | 0.8 | 0.5 | 0.3 | 1.1 |
| Netherlands | 0.5 | 0.1 | 0.8 | 0.4 | 1.0 | 0.7 | 0.1 | 0.5 |
| Sweden | 0.5 | 0.6 | 0.8 | 0.3 | 0.4 | 0.3 | 0.1 | 0.2 |
| Taiwan | 0.1 | 0.0 | 0.0 | 0.2 | 0.0 | 0.1 | 0.0 | 0.2 |
| South Korea | 0.1 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 |

Sources: National Science Board (1991); DIW calculations.

## Table 8

### Balance of Affiliates R&D between the Federal Republic of Germany and the United States 1980 - 1992

| Year | R&D expenditure in $ million | | | Employment in 1000s | | for information: rate of exchange[1] in Germany |
|---|---|---|---|---|---|---|
| | German companies in the United States total | American companies in Germany | | American companies in Germany | | |
| | | total | of which: manufacturing | total | of which: manufacturing | $ 1 |
| 1980 | 380 | - | - | - | - | 1.8158 |
| 1982 | - | 893 | 847 | 502.1 | 404.2 | 2.2487 |
| 1987 | 1 139 | - | - | - | - | 1.7982 |
| 1989 | 1 474 | 1 496 | 1 459 | 493.7 | 383.7 | 1.8813 |
| 1990 | 1 764 | 2 561 | 2 431 | 529.7 | 401.1 | 1.6161 |
| 1991 | 1 676 | 2 503 | 2 384 | 530.3 | 394.1 | 1.6612 |
| 1992 | 1 937 | 2 707 | 2 601 | 541.0 | 418.6 | 1.5595 |

1) Annual average.
Soures: U.S. Department of Commerce; Deutsche Bundesbank.

research intensity among American affiliates in Germany. In 1991 the biggest share — almost 30 percent — of R&D spending by American affiliates abroad came to the Federal Republic. At 2.5 per cent, R&D intensity (R&D expenditures as a percentage of turnover) in manufacturing affiliates in Germany is higher than it is in affiliates located in Japan, the United Kingdom, or France. In comparison to American affiliates in these countries, those in Germany have the highest R&D expenditure per employee in vehicle construction, mechanical engineering, and the food industry (Table 9).

Whereas in the early nineties Germany ranked first among the target countries for R&D spending by American enterprises, it came only third (1990) or fourth (1991) in regard to R&D expenditure in foreign affiliates in the United States. Companies from Canada, Britain, and Switzerland spent more on research in the United States than did German affiliates in 1991. As far as R&D intensity was concerned, German companies in the late eighties and early nineties ranked second or third in the United States after Swiss and Canadian enterprises.

All these indicators point to very strong intra-group networking in R&D between companies in the United States and the Federal Republic. The growing commitment of German companies to research in affiliates in other countries followed growing direct investments abroad and the general trend among multinationals to distribute production-unrelated, basic research throughout the world rather than having it conducted only at the location of the parent company. There is a lack of information on the research orientation and research intensity of foreign affiliates in the Federal Republic. American direct-investment statistics provide an insight into the research activities of American affiliates in Germany. For these companies, the Federal Republic of Germany has apparently retained its attractiveness as a location for research in the early nineties.

## Table 9

### R&D Spending per Employee in American Affiliates Abroad in 1991 in $s

| Sector | Parent companies in the United States | American affiliates | | | | |
|---|---|---|---|---|---|---|
| | | World-wide | of which in: | | | |
| | | | Germany | Britain | France | Japan |
| Manufacuring | 6 177 | 2 444 | 6 049 | 3 095 | 3 408 | 5 541 |
| Food and kindred products | 949 | 663 | 1 797 | 1 622 | 821 | 0 |
| Chemical and allied products | 11 969 | 4 716 | 6 096 | 8 585 | 10 796 | 8 923 |
| Primary and fabricated metals | 1 594 | 612 | 1 754 | 808 | 1 383 | 2 857 |
| Machinery, exept electrical | 11 995 | 3 042 | 3 863 | 2 244 | 804 | 1 230 |
| Electric & electronic equipment | 6 270 | 1 521 | 3 973 | 1 421 | 1 262 | 8 000 |
| Transportation equipment | 7 412 | 3 753 | 10 525 | 3 635 | 3 741 | 5 714 |
| Other manufacturing | 3 210 | 1 328 | 2 981 | 1 735 | 1 888 | 0 |
| for information: Share of R&D expenditure by American affiliates in global manufacturing in % | - | 100.0 | 29.6 | 17.1 | 8.5 | 5.6 |
| R&D intensity in manufacturing in % [1] | 3.74 | 1.35 | 2.47 | 1.52 | 1.51 | 1.73 |

1) R&D expenditure as a percent of turnover.
Sources: U.S. Department of Commerce; DIW calculations.

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