B 2 INTERNATIONAL R&D LOCATIONS

B 2–1 TRENDS IN R&D GLOBALISATION

The internationalisation of research and development (R&D) is continuously progressing and will become increasingly relevant also in the years to come. R&D globalisation leads to a relocation of R&D sites and a new balance of power in the world economy. This will have a major impact on Germany's policy options in the field of research and innovation.

One of the main reasons behind the ongoing internationalisation of R&D are the development strategies of numerous countries that are strengthening their efforts in the field of R&D and innovation. Major challenges, particularly those addressed by the priority areas of the Federal Government's High-Tech Strategy, are yet another reason for pursuing targeted and cooperative efforts across national boundaries. In addition to this, there is an emerging trend towards open, globally distributed innovation systems (open innovation). Finally, new information and communication technologies are reinforcing the trend towards open, globally distributed innovation processes.

The key players here are large R&D intensive multinational corporations that are spurring the development and worldwide distribution of products. High fixed costs for R&D and accelerated product cycles lead to the fact that amortisation in highly dynamic product segments can only be achieved through global operations. As a result, more and more companies are forced to position themselves on the global market – especially by means of R&D and production sites in several international locations.

The internationalisation of R&D activities is spurred on primarily by industries that are R&D-intensive and that are characterised by short development cycles, which is particularly the case in cutting-edge technology. The pharmaceutical industries and the electronics, telecommunications, information technology and software industries display a particularly high proportion of R&D expenditure abroad. But also in export industries such as the automotive, mechanical engineering and chemical industries – all of which play an important role for Germany's economy – foreign R&D activities are becoming increasingly important.

There are several key motives for conducting R&D abroad:
- market-seeking motives
- resource-seeking motives (R&D-related and technological motives)
- production and engineering driven motives (related to the production and value creation system)
- reactions to political and legislative conditions that make it necessary to conduct R&D simultaneously at several locations.

As regards market-seeking motives, surveys frequently mention the size and the growth of certain target markets as decisive factors, as well as the important role of individual lead markets. The capacity of a national market to absorb innovative products and the innovation orientation of local clients provides strong incentives for being in close proximity to customers, also in terms of R&D activities.

Resource-seeking motives refer to the availability of research resources and research findings, access to talent, and the opportunity to conduct R&D at reasonable costs. R&D centres are established primarily at locations that feature particularly high numbers of STEM subject graduates.

Another reason for the globalisation of R&D centres is the ongoing development of global production and value chains.[230] In many sectors, innovation success depends on close geographical proximity, manufacturing know-how, and simultaneous product and process development. Once multinational enterprises (MNEs) have established production plants in foreign locations, it will not be long until they also establish local development and engineering centres.

The internationalisation of R&D is also increasingly influenced by political and legal framework conditions. Differing regulations and standards make it necessary to develop and adapt products in several countries.[231] In addition, more and more countries are demanding a stronger local presence and higher domestic value-added shares, also known as local content requirements, with the aim of developing high-value production structures and securing

technology transfer. Thus many countries demand that foreign MNEs strengthen their commitment to conducting R&D locally.[232] Especially in cases where public procurement plays a key role in the evolution of demand, companies that are present with local R&D sites will be treated more favourably.[233]

To quite a large extent, the internationalisation of R&D is also the result of acquisitions. Companies with existing research structures are often acquired, particularly in highly developed countries. Thus periods of extensive mergers and acquisitions activities are accompanied by an increased internationalisation of R&D. Yet this does not necessarily imply that new R&D capacities have been expanded – a fact that should also be taken into account when interpreting statistics on the internationalisation of R&D, if valid assessments and policy recommendations are to be derived.

However, it is important to differentiate long-term, stable structures from short-term changes. In the field of R&D, investor structures are relatively stable. The majority of investors come from highly developed countries that are well endowed with domestic multinational corporations, which also take on the role of major donors for foreign direct investment. By far the largest proportion of investors is made up of MNEs from the United States, followed by enterprises from Switzerland, Germany, Sweden and Japan.[234] In 2008, MNEs from the US invested a total of EUR 25 billion in foreign R&D activities.[235] Between 1998 and 2008, the foreign share of R&D expenditure of these companies increased from 13 percent to 16 percent.[236] In some smaller countries that have strong domestic MNEs, the proportion of foreign R&D is above 50 percent.

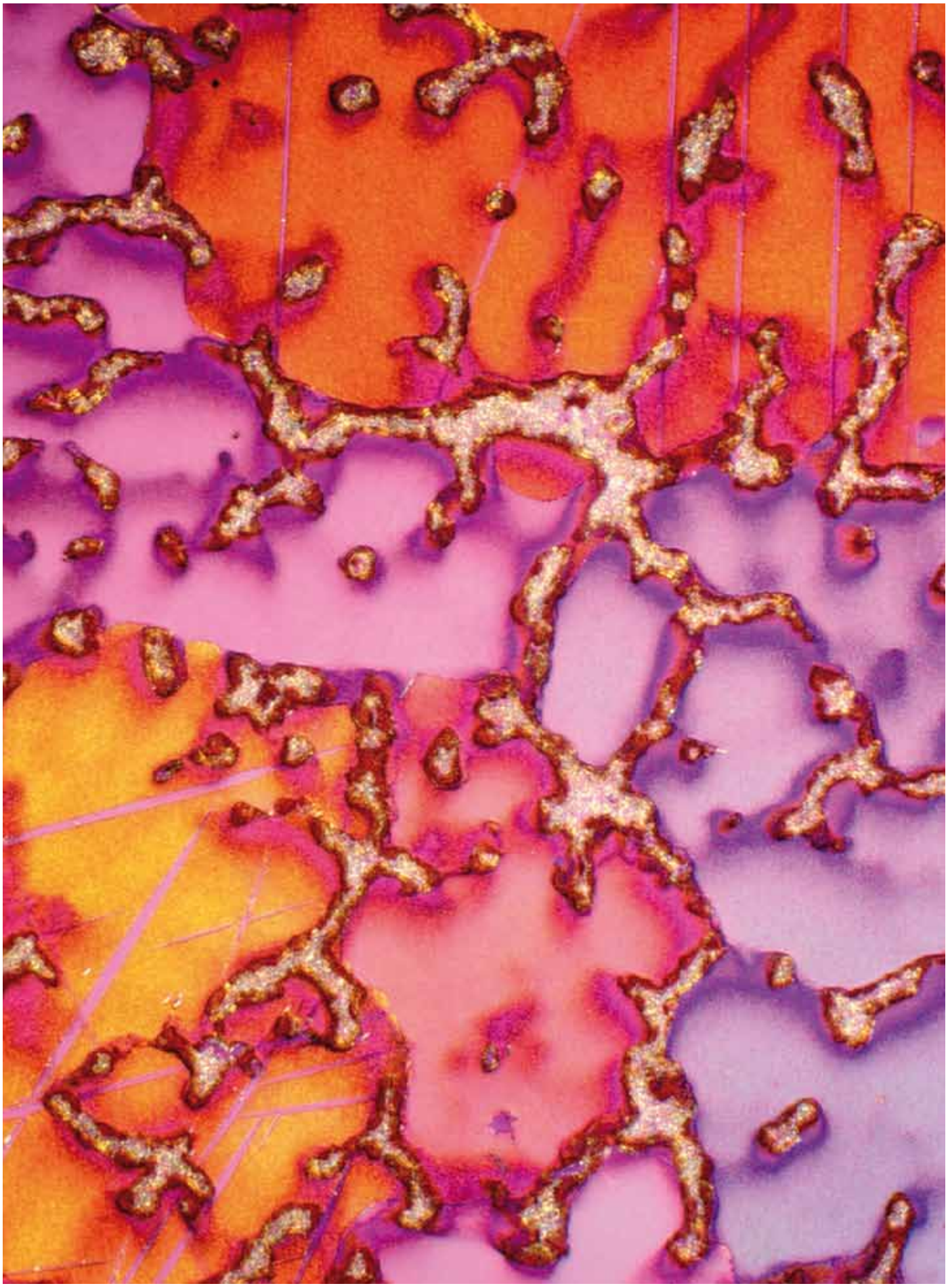
A considerable increase in foreign R&D investment could be observed between Europe and the United States and between Asia and the United States. Investment flows with Asian countries and developing countries are also becoming increasingly important. The 1990s and the beginning of the new millennium were dominated by foreign R&D activities of companies within the Triad countries. Here, US companies in Western Europe and Western European companies in the United States accounted for the largest share of investments. Only in recent years, a shift towards new target countries outside the Triad countries has been taking place.

With regard to the structure of the target countries for R&D investments, emerging changes are more pronounced than changes in the investor countries. Yet this does by no means imply that "classical" locations are swiftly replaced by new locations. As a location for foreign R&D investment, the United States continue to dominate the scene, with foreign MNEs investing a total of EUR 35 billion in R&D in 2009. The proportion of industrial R&D investment in the United States attributable to subsidiaries of foreign MNEs increased from 13 percent in 2000 to 15 percent in 2009. As a location for foreign R&D investments, Germany fills the important second position, followed by the UK and France.[237]

Table 4 displays the ranking of target countries for MNEs' R&D investments (as measured by R&D expenditure in billion euro in 2009) for selected OECD countries.

The share of R&D expenditures of foreign affiliates as a percentage of R&D expenditures of the business sector is not only a sound indicator of a country's attractiveness, but also for its dependency on foreign investors (cf. the right column of Table 4). A high value (e.g. above 50 percent) indicates a high dependency on foreign companies' management decisions, while a low value (e.g. less than 10 percent) indicates that foreign investors find impeding conditions for conducting R&D (e.g. Japan), or assess the target country's technological competencies as being limited. Some smaller countries, such as Israel, Ireland and the Czech Republic, have 60 to 70 percent shares of foreign investors. These countries make themselves dependent on foreign companies' investment deci-sions, since MNEs may relocate their R&D investments at any time.[238]

The BRIC countries and, especially, the emerging economies in Asia are playing an increasingly important role as locations for R&D investments by foreign companies. Yet these countries are not fully accounted for in official statistics. Only the most recent EU study[239] on the internationalisation of R&D addresses the interdependencies between the EU and key Asian countries. Figure 5 displays the worldwide interdependencies of R&D investments between the EU, Switzerland, China, Japan and the USA for the year 2007.



Magensium alloy.

View inside a low-pressure plasma reactor at the Fraunhofer IFAM's PLATO section.

TAB 04 **Ranking of target countries for foreign R&D expenditures of multinational companies (selected OECD member countries)**

	R&D expenditures of subsidiaries of foreign MNEs in 2009 (in billion euro)	Share of foreign MNEs' R&D expenditures as a percentage of business R&D expenditures in 2009
USA	34.8	15.4
Germany	*12.2*	*27.3*
Great Britain	8.8	46.7
France	4.8	19.6
Japan	4.9[2]	5.1[2]
Israel	3.8[2]	61.8[2]
Canada	3.3	32.6
Australia	3.0	32.1
Italy	2.6	24.5
Austria	2.5	52.3
Belgium	2.3	53.8
Sweden	2.1	29.6
Netherlands	1.6[1]	32.6[1]
Spain	1.5[2]	34.3[2]
Ireland	1.2	69.9
Czech Republic	1.0	58.0
Finland	0.7[1]	16.0[1]
Poland	0.5	50.5
Norway	0.5[2]	30.5[2]
Hungary	0.4	52.6

[1] 2008 figures, [2] 2007 figures.
Source: own depiction based on OECD, Main Science and Technology Indicators, Volume 2012/1.

In the medium term, major structural shifts away from the "traditional" target countries for R&D investments are likely to occur. It can be observed that Asia's R&D system is growing much faster than that of the highly developed Triad countries. Between 1996 and 2007, China's national R&D expenditure increased by 22 percent annually. Korea's annual growth rate was 12 percent, with Taiwan at 10.5 percent and Singapore at 9.5 percent. In the same period, national R&D expenditure in the United States, the EU and Japan increased by only 5.4 to 5.8 percent. MNEs are thus provided with further incentives for establishing locations in some of the world's most dynamic R&D regions.

Against this background, there has been an increasing shift of R&D investments towards aspiring emerging economies – a trend that is certainly going to progress in the future. Investment flows are primarily focussed on BRIC countries, and a particularly strong increase can be observed in China. Other important new R&D locations for MNEs include Singapore, India and Israel, as well as selected Eastern European countries.

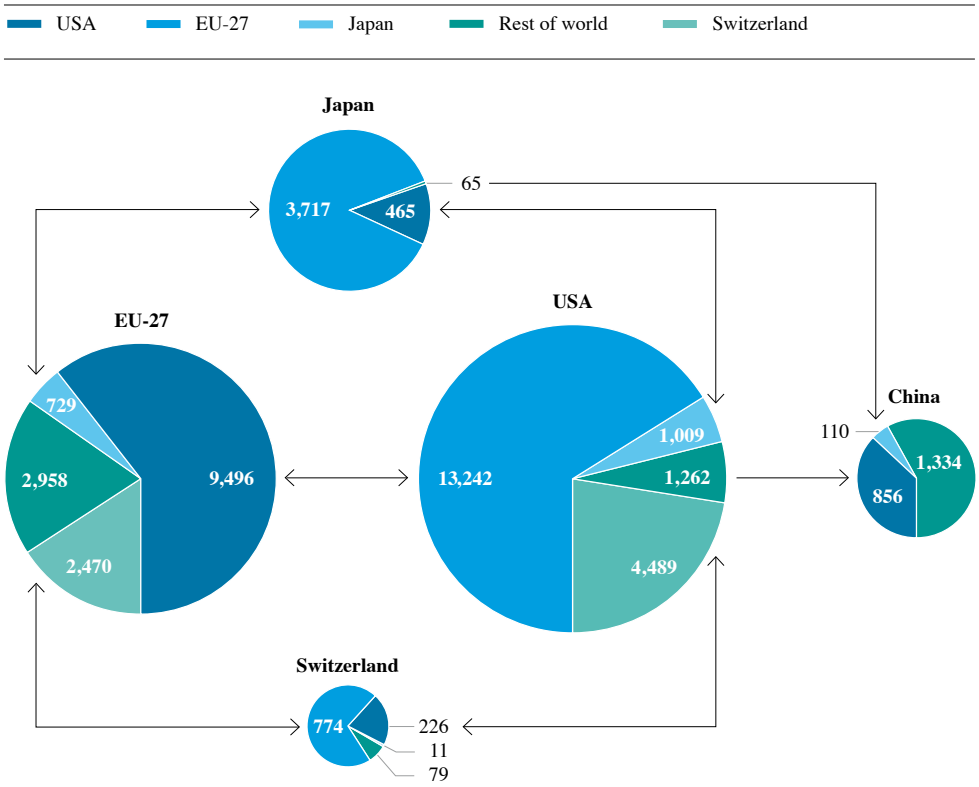
Over a period of ten years (between 1998 and 2007), Asia's share of foreign R&D expenditure by US-based MNEs increased from 11 percent to 20 percent. Within the same period, Europe's and Canada's shares decreased from 83 to 74 percent. Similar structural shifts can be observed in terms of R&D investments by foreign MNEs from Western Europe and Japan. In future, the structure of the global R&D system will be much more multipolar. This ongoing trend entails serious consequences for national research and innovation policies.

FOREIGN R&D INVESTMENTS BY GERMAN COMPANIES B 2–2

German companies are represented at many locations across the globe – not only with sales offices and production facilities. To an increasing extent, German companies have to secure key markets through research and product development on site. In 2009, German companies spent a total of EUR 11.3 billion on foreign R&D. German companies highly prioritise their foreign R&D activities. Foreign and domestic R&D activities are often characterised by a division of labour and tend to reinforce each other in a complementary manner. In this respect, an increase in foreign R&D investments could be assessed positively as such investments will also augment Germany's position as an innovation hub. Yet this can also lead to temporary adverse effects, which is e.g. the case when foreign R&D is increased at the expense of domestic capacities, or when promising research areas are no longer pursued at the home base.[240]

In the 1990s, foreign R&D investments experienced a sharp upward trend. Between 1995 and 2001, R&D investments of foreign affiliates of German MNEs increased from EUR 5 billion to EUR 12 billion (cf. Table 5). During this period, the foreign R&D share increased from 23 percent to nearly 35 percent. German companies followed the overall globalisation trend of R&D and proved to be very active in the United States and in a number of European and Asian countries.

FIG 05 **Inward BERD relations between the EU-27, the USA and selected other locations in 2007**



Comment: companies from the EU-27 invested EUR 774 million in R&D in Switzerland in 2007; Swiss companies invested EUR 2,470 million in R&D in the EU-27 in 2007.
Figures for Switzerland include the services sector; figures for China estimated based on national data and data on foreign R&D by the United States and Japan.
Source: *Europäische Kommission* (2012b: 29).

TAB 05 **Structure of R&D expenditures of German MNEs 1995 to 2009**

	1995	2001	2007	2009
Foreign R&D expenditures of German companies (billion euro)	5.1	11.9	9.4	11.3
Domestic R&D expenditures of German companies (billion euro)	17.0	22.5	29.2	30.1
Total R&D expenditures of German companies (billion euro)	22.1	34.4	38.6	41.4
Share of foreign R&D expenditures as a percentage of total R&D expenditures	**23.1**	**34.6**	**24.4**	**27. 3**

Source: Own depiction based on IWH et al. (2013).

Foreign R&D expenditures of German companies by industry 2001 to 2009 TAB 06

Industry	2001	2005	2007	2009
	R&D expenditures of German companies abroad (billion euro)			
Manufacturing	11.6	11.3	8.8	10.7
Chemical industry	3.6[a]	1.2	1.6	0.7
Pharmaceutical industry		2.1	2.1	3.7
Mechanical engineering	0.4	0.7	0.8	0.5
Computer, electrical engineering, optics	2.8	2.3	1.2	1.8
Automotive engineering	4.6[b]	4.8	3.0	3.6
Remaining sectors	0.4	0.2	0.6	0.6
Enterprise sector in total	11.6	11.4	9.4	11.3
	Proportion of German companies' foreign R&D expenditures in percent			
Manufacturing	36.4	30.7	24.2	27.4
Chemical industry	48.0[a]	29.7	29.9	25.4
Pharmaceutical industry		51.8	69.2	54.0
Mechanical engineering	39.5	27.2	29.4	19.5
Computer, electrical engineering, optics	37.4	31.6	20.2	33.2
Automotive engineering	30.1[b]	26.5	15.6	18.3
Remaining sectors	13.7	10.1	27.3	25.7
Enterprise sector in total	34.7	29.9	24.4	27.3

[a] The values for the chemical and pharmaceutical industries are not separately identifiable for the year 2001.
[b] Vehicle construction
Source: Own depiction based on IWH et al. (2013).

The years 2002 to 2007 saw a temporary return to investments in domestic R&D. In the preceding years, the number of foreign R&D sites had increased considerably, which resulted in coordination issues in transnational project collaboration.[241] By 2007, foreign R&D expenditure of German companies had temporarily decreased from EUR 11.9 billion to EUR 9.4 billion. In the period 2002 to 2007, domestic R&D expenditure increased from EUR 22.5 billion to EUR 29.2 billion (cf. Table 5). A new surge in the globalisation of German R&D could be observed since 2008. Since then, foreign R&D expenditure has been growing much faster than domestic R&D expenditure. The increase of foreign exports and foreign investments following the financial crisis was partially driven by an increase in foreign R&D activities, especially in the emerging economies.

The manufacturing industries are a major driving force behind the internationalisation of R&D.[242] Strong export activities will lead to the creation of local production sites and an increase in direct investments, albeit with a certain delay. This will attract further R&D investments from abroad. As a result, foreign R&D investments of German companies are concentrated on a limited number of export sectors. Thus, automotive engineering alone accounts for 38 percent of foreign investment by Germany's private sector, with a total R&D expenditure of EUR 3.6 billion. Another EUR 3 billion (27 percent) are attributable to mechanical engineering, electrical engineering and the chemical industries. Germany's pharmaceutical industry is also very active as an investor in foreign R&D. Thus, between 2003 and 2009, the pharmaceutical industry's foreign R&D expenditure more than doubled (with EUR 3.7 billion in 2009). In the pharmaceutical industry, the share of foreign R&D amounts to more than 50 percent, while other sectors invest between 20 and 33 percent of total R&D expenditure abroad (cf. Table 6).

The United States continue to be the most important foreign R&D location for German companies, which is largely owing to high R&D investments

in the pharmaceutical and electrical engineering industries. In 2009, one third of the German enterprise sector's foreign R&D investment was allocated to locations in the United States (a total of EUR 3.8 billion). Other important target countries include Austria (EUR 1.3 billion), France (EUR 0.8 billion), the UK (EUR 0.4 billion) and Switzerland (EUR 0.4 billion)[243]. Following in sixth position is Japan with a total of EUR 0.3 billion foreign R&D. Figures are based on estimates by the German Institute for Economic Research *(DIW Berlin)*. Figures on the enterprise sector's foreign R&D expenditure are currently not fully recorded by the *SV Wissenschaftsstatistik.*[244] Especially R&D investments by German companies in important emerging economies (China, India, Brazil, and Russia) have been documented only partially to date.

Besides the *SV Wissenschaftsstatistik,* the *Deutsche Bundesbank* also publishes data on cross-border R&D expenditures of German companies with foreign affiliates (cf. Table 7). While these figures only cover a fraction of all foreign R&D spending by German companies, they still allow for conclusions regarding the relevance of key target countries. The data provided by the *Deutsche Bundesbank* primarily relate to payments of German-based corporate research units to subordinate research units abroad. This does not include foreign R&D expenditures in application-oriented research funded by foreign business units. These application-oriented R&D expenditures tend to be several times larger than corporate R&D expenditures.

Despite the fact that available data on R&D expenditure are limited, foreign R&D activities of German companies can still be analysed by examining recent patent statistics. These statistics itemise the inventors' place of residence and the location of the patent-filing enterprise. Thus, when analysing patent applications of German companies that involve inventors domiciled abroad, conclusions can be drawn regarding the presence of German companies in certain target countries. From the inventor's place of residence it can be indirectly concluded that the respective research was also conducted in the country concerned.[245] Furthermore, the patent class, also itemised in the patent statistics, provides indications on the technological fields in which individual companies are active in specific countries.[246]

Cross-border foreign R&D expenditures of German companies (mainly corporate headquarters' expenditures) TAB 07

	R&D expenditure in 2011 (billion euro)	Target country's share in recorded foreign R&D expenditures (in %)
1. USA	0.78	18.0
2. Austria	0.53	12.1
3. France	0.50	11.7
4. Switzerland	0.34	7.9
5. Great Britain	0.34	7.8
6. Japan	0.26	6.1
7. Italy	0.19	4.4
8. India	0.15	3.4
9. China	0.12	2.7
10. Netherlands	0.10	2.3
Rest of world	1.02	23.5

Source: own depiction based on IWH et al. (2013).

The relevance of foreign inventors within German companies, as measured by the German Applications of Foreign Inventions (GAFI) indicator, has steadily increased over time. The GAFI indicator refers to patent applications with at least one inventor residing outside of Germany and one applicant based in Germany. To determine the GAFI ratio, the GAFI value is calculated in relation to the total number of patents filed by German applicants. In 1991, the GAFI ratio was 8 percent; it rose to 13 percent by 2000 and reached a value of almost 16 percent in 2009. The GAFI indicator is used to detect long-term trends, even though it can only be used as a proxy variable for foreign R&D activity.[247]

What is striking is the relatively high number of inventions filed by researchers residing in the Netherlands and Switzerland. These values tend to be significantly higher than the R&D expenditure in the respective countries, as indicated in the previous section. The GAFI ratios of different countries have displayed considerable structural changes over time. Thus, for instance, the relevance of foreign inventors in the United States has decreased from 26.5 percent between 1991 and 1994 to 19.4 percent between 2006 and 2009. Within the same period, the relevance of foreign inventors in the UK and Japan has declined from 10.4 percent to 7.0 percent and from 4.9 percent to 3.0 percent respectively. A

considerable increase could be observed regarding inventors residing in the Netherlands, a country that has doubled its GAFI ratio since 2000.[248]

Patent figures are also suited to record emerging countries as R&D locations. A growing proportion of patents filed at the European Patent Office refer to inventions involving researchers residing in China. The GAFI ratio for China rose from 0.3 to 3.7 percent (cf. Table 8). An increase in the GAFI ratio has also been recorded for other countries, among them India, Hungary, the Czech Republic and Brazil.[249] Meanwhile, the relevance of the Russian Federation as a R&D location for German enterprises has declined over time. With a GAFI ratio of 1.9 percent between 1991 and 1994, Russia still ranked in first place within the BRIC countries. However, between 2006 and 2009, this share fell to 0.8 percent and Russia was overtaken not only by China, but also by India, Brazil, Hungary and the Czech Republic.

An analysis based on the GAFI indicator also provides information regarding the industries and fields of technology that German companies with inventions in foreign R&D locations are active in. In the United States, German companies are strongly active in the following areas in which foreign inventors have been recorded: computer technology, pharmaceuticals, biotechnology, organic fine chemistry and basic materials chemistry. German companies, by contrast, tend to be less active with R&D in the United States in the areas of transport technologies, thermal processes and apparatus, motors, pumps and turbines, medical instruments, measurement, digital communication technology, as well as electrical machinery and apparatus.

German companies thus tend to employ large numbers of foreign inventors in the United States in research areas in which the United States are technological leaders (e.g. computer technology, pharmaceuticals and biotechnology). At the same time, German companies in the United States conduct relatively little research in areas where the relevant technological expertise is to be found in Germany or in other countries (e.g. in the fields of transport, engine and turbine construction and measurement).

It is also worthwhile comparing the foreign inventive activities of German companies with the respective foreign inventive activities of US companies.[250]

Ranking of important foreign invention locations for German companies TAB 08

Foreign inventor locations	GAFI ratio 2006–09 (%)	GAFI ratio 1991–94 (%)
Major existing foreign inventor locations		
1. USA	19.4	26.5
2. Netherlands	12.1	5.5
3. France	9.6	9.2
4. Switzerland	9.0	5.7
5. Austria	8.5	9.8
6. Great Britain	7.0	10.4
7. Italy	4.3	3.4
8. Belgium	3.4	4.9
9. Spain	3.3	2.7
10. Japan	3.0	4.9
New foreign inventor locations		
China	3.7	0.3
India	1.0	0.4
Czech Republic	0.9	0.3
Hungary	0.9	0.5
Brazil	0.9	0.4
Russia	0.8	1.9
Australia	0.8	0.7
Poland	0.6	0.3
Korea	0.5	0.1
Slovenia	0.5	0.2

The GAFI indicator refers to patent applications with at least one inventor residing outside of Germany and one applicant based in Germany. To determine the GAFI ratio, the GAFI value is calculated in relation to the total number of patents filed by at least one applicant based in Germany.
Source: own depiction based on IWH et al. (2013).

Thus, for instance, it can be observed that in the pharmaceutical, biotechnology, semiconductor and computer technology industries, Germany is far more dependent on foreign inventions than the US. At the same time, when compared with Germany, the United States are much more dependent on foreign inventions in the fields of transport technologies, machine tools, optics and civil engineering.[251]

Conclusions on the international division of labour can also be drawn by examining the distribution of competencies between Germany and other target countries. For instance, German companies with foreign inventors operate in China in the following areas: basic materials chemistry, macromolecular chemistry,

polymers, organic fine chemistry, and electrical and energy engineering. At the same time, German companies with foreign inventors in China record relatively low numbers of inventions in the following areas: transport, thermal processes and apparatus, motors, pumps and turbines, machine tools, food chemistry, pharmaceuticals, medical instruments and optics.[252]

US companies with R&D activities in China are focussing on quite different areas. Thus, in the fields of computer technology and communication technology, US companies display a relatively high number of foreign inventors who are domiciled in China. As China has been developing these areas in particular, it is now closely linked with US enterprises through transnational value chains.

B 2–3 GERMANY AS AN R&D LOCATION FOR FOREIGN COMPANIES

Germany is a core location within a dense network of R&D related to foreign direct investment. While the United States are the most important hub within this network, Germany is occupying an important second position. Germany's strongest links are with the United States and several European countries. Germany plays a major role as a location for R&D subsidiaries of foreign MNEs and has been able to continuously advance its position over the last two decades.[253] In 2009, foreign MNEs invested EUR 12.3 billion in R&D in Germany, while employing a staff of 85,000 R&D fulltime equivalents, which amounts to approximately one quarter of the German economy's total R&D personnel.[254]

The relevance of foreign companies as R&D investors within the German innovation system has increased steadily since the early 1990s. While their shares in the R&D expenditure of Germany's business sector had amounted to 16 percent in 1993, this figure went up to 25 percent in 2001 and reached 27 percent by 2009. Table 9 shows a comparison of the R&D expenditure of foreign MNEs in Germany and the domestic R&D expenditure of German companies. While German companies increased their R&D expenditure between 1995 and 2009 by approximately 50 percent in nominal terms, foreign companies almost tripled their R&D expenditure in Germany during the same period. A significant part of this increase is attributable to business acquisitions.

Foreign enterprises are making a lasting contribution to technological development in Germany and are major employers of highly skilled workers. Between 1997 and 2009, R&D staff levels in subsidiaries of MNEs were increased by 37,500 jobs in total. A substantial part of this increase is the result of acquisitions of German companies by foreign MNEs. During the same period, the number of R&D personnel in German companies remained almost stable.[255]

Table 10 shows the importance of key industries in which foreign companies play a major role in implementing R&D and securing employment in Germany. The manufacturing industries remain at the forefront here; especially the electrical, vehicle construction, chemical and pharmaceutical industries, as well as mechanical engineering. The main areas in which foreign companies provide employment in R&D are largely identical with those fields that German companies also excel in. The proportion of foreign R&D employers in Germany is particularly high in other transport equipment – especially in the aerospace industry (81 percent) – and in the pharmaceutical industry (44 percent). In electrical engineering (including computer technology) the proportion of foreign companies amounts to 29 percent. Yet, in contrast to other industries, an increase in foreign R&D employment has not been recorded in recent years. Throughout the last decade, a considerable decline has been recorded in the field of computer technology, where a significant shift towards the Asian markets could be observed. In addition to manufacturing, the services sector is playing an increasingly important role for foreign R&D employment. Particularly in the areas of business services and information and communication services, the number of R&D personnel employed by MNEs increased from 2,200 to 9,300 over the past decade.

Foreign companies focus their R&D activities on industries and technology fields in which Germany has proven technological expertise and in which the research priorities of domestic enterprises are reflected. Existing strengths are thus further reinforced. It is only rarely the case that foreign investors develop new fields of competence in Germany. Acquisitions of existing businesses and the creation of R&D sites in the vicinity of existing R&D centres of German companies are strong driving forces here. Both factors

Structure of business R&D expenditures in Germany between 1995 and 2009

TAB 09

	1995	2001	2007	2009
R&D expenditures of foreign MNEs in Germany (billion euro)	4.3	8.9	11.2	12.3
Domestic R&D expenditures of German companies (billion euro)	22.4	27.1	31.6	32.7
Total business R&D expenditures in Germany (billion euro)	26.7	36.0	42.8	45.0
R&D expenditures of foreign affiliates as a percentage of total business R&D expenditures in Germany	16.1	24.8	26.3	27.3

Source: own depiction based on IWH et al. (2013)

R&D personnel of companies in Germany between 1997 and 2009, according to industries

TAB 10

	1997	2001	2007	2009
R&D personnel employed in German subsidiaries of foreign MNEs (full-time equivalents)	47,500	73,200	81,136	84,975
R&D personnel employed in German companies in Germany (full-time equivalents)	238,770	234,057	240,717	247,516
Share of foreign companies' personnel as a percentage of private R&D personnel in Germany	16.6	23.8	25.2	25.6
R&D personnel in foreign MNEs according to industries (full-time equivalents)				
Chemicals / pharmaceuticals	6,900	11,250	14,372	12,129
Mechanical engineering	5,900	7,500	7,741	7,878
Electrical engineering / computer	17,900	20,300	20,763	18,247
Vehicle construction	11,200	21,700	24,840	25,865
Business services	–	4,177	4,253	4,288
Information and communication	–	–	–	4,986
Foreign MNEs' personnel as a percentage of industry-specific R&D personnel				
Chemicals / pharmaceuticals	14.6	26.7	34.7	29.9
Mechanical engineering	15.0	20.1	18.4	20.8
Electrical engineering / computer	24.9	25.4	29.2	28.9
Vehicle construction	13.7	24.6	25.6	26.1
Business services	–	20.1	12.6	19.6
Information and communication	–	–	–	226

Source: own depiction based on IWH et al. (2013)

tend to have a preserving effect, rather than stimulating the creation of new areas of competence in Germany. As this is an obvious deficit, Germany will have to develop new strenghts also in the area of cutting-edge technology – precisely the area in which foreign MNEs are the main investors.

In order to analyse R&D and invention activities of foreign companies, indicators from patent statistics are used to complement available data. The increasing activity of foreign patent applicants involving German inventors is measured by the FAGI indicator (Foreign Applicants of German Inventions). The FAGI value serves as an indicator of research and invention activities of foreign companies located in Germany, since the presence of inventors in Germany suggests that the corresponding R&D work was also conducted in Germany.[256] The FAGI ratios in the periods from 1991 to 1994 and from 2006 to 2009 increased continuously. The importance of patent applications by foreign MNEs involving German inventors increases over time. Over the last 15 years, however, significant structural shifts have occurred regarding the home base of the applicants. These are summarised in Table 11. Especially businesses from the US, Switzerland, the Netherlands and France are dominating the scene. Between 2006 and 2009, the overall relevance of patent-filing enterprises based in France, Finland, Japan and Sweden has increased. This is complemented by growing numbers of MNEs from emerging economies – especially companies from China and Korea as well as Central and Eastern Europe, all of which also employ inventors residing in Germany.

Share of foreign applicants with inventors residing in Germany (FAGI ratio) TAB 11

Applicants' country of residence	FAGI ratio 2006–09 (%)	FAGI ratio 1991–94 (%)
Existing important countries of residence		
1. USA	28.7	29.9
2. Switzerland	23.1	22.8
3. France	11.1	8.9
4. Netherlands	5.6	14.4
5. Finland	4.7	0.4
6. Japan	4.6	2.3
7. Sweden	4.4	2.3
8. Austria	4.0	4.3
9. Belgium	2.7	2.8
10. Great Britain	2.1	5.4
New countries of residence		
China	0.5	0.0
Korea	0.4	0.0
Australia	0.3	0.3
Israel	0.2	0.4
India	0.1	0.0
Russia	0.1	0.2
Poland	0.1	0.0
Czech Republic	0.1	0.0
Hungary	0.1	0.0
Turkey	0.1	0.0

The FAGI indicator refers to patent applications with at least one inventor residing in Germany (German inventor) and one applicant residing outside of Germany (foreign applicant). To determine the FAGI ratio, the FAGI value is calculated in relation to the total number of patent applications with at least one German inventor.
Source: own depiction based on IWH et al. (2013)

An analysis of the FAGI ratios also allows for an assessment regarding the competencies that companies from specific countries are seeking in their R&D activities in Germany. Companies from the United States continue to make up the largest group. These focus their research in Germany on the areas of transportation (8 percent of patents filed by US companies), medical instruments (8 percent), and electrical machinery and apparatus (7 percent). Yet in other fields of technology, US companies are not very active in Germany. US companies tend to prefer international locations other than Germany when it comes to R&D in the field of pharmaceuticals, biotechnology, and semiconductor and communication technology.

The research and invention activities of Western European companies are partially focussed on the same fields. Yet it has also become apparent that applicants from specific home countries have specific technology profiles. Particularly striking is the strong focus on medical instruments (15 percent) by Swiss companies in Germany, as well as the strong focus on digital communication by businesses from France, the UK and the Netherlands.[257]

Germany's technological fields of competence can also be assessed through a comparative analysis with the foreign R&D portfolio of US-based corporations. Germany continues to be not only the most important foreign R&D location for US

companies, but also the second-most important location for inventors after the United States. That said, a number of emerging economies are increasingly competing with Germany as a location for R&D, among them China, India and Israel. When analysing the profile of foreign inventions by applicants from the United States, and specifically the profile of inventions in Germany, it turns out that the commitment of US companies continues to be high in technology areas in which Germany has been traditionally strong. This applies to the following areas in particular: motors, pumps and turbines, medical instruments, as well as electrical machinery and apparatus. At the same time it also becomes apparent in which fields US companies have ceased to conduct research in Germany and have instead relocated to other, more renowned R&D locations. In the field of computer technology for instance, US companies are much more present in the UK and in China, while India serves US companies as a location for R&D in data processing and IT services. US companies increasingly choose emerging economies as locations for their R&D, especially in the area of cutting-edge technologies. A detailed analysis of foreign patenting profiles of MNEs from different nations could serve as a useful diagnostic tool to assess Germany's technological performance.

B 2–4 FOREIGN R&D ACTIVITIES IN EUROPE

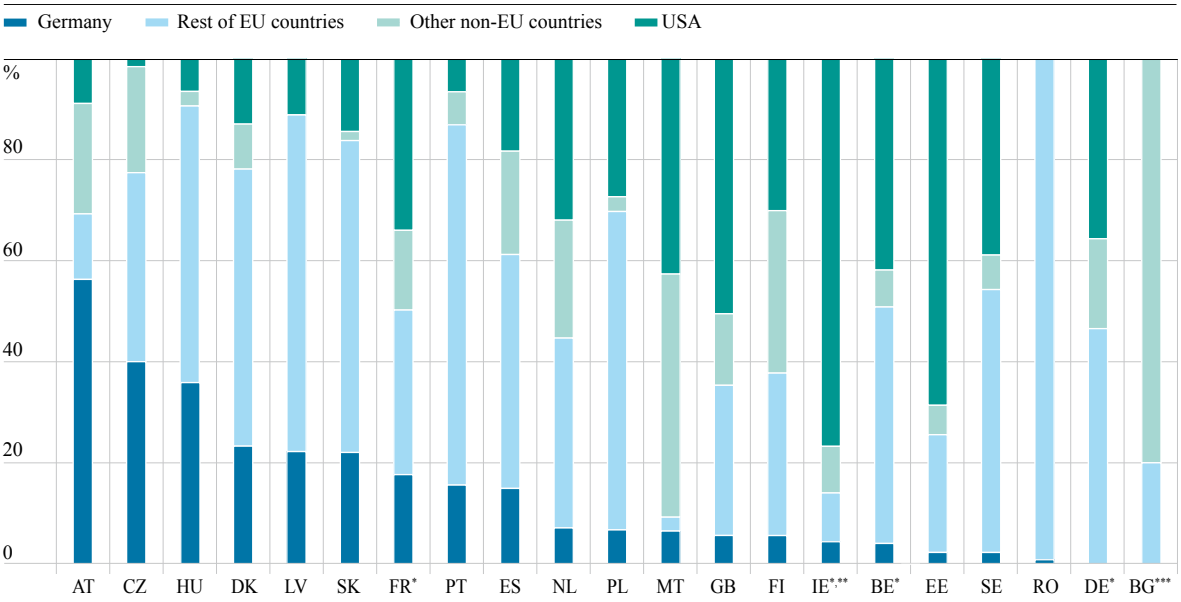
In the EU 27, the distribution of domestic patents with at least one domestic inventor and at least one foreign applicant – which serves as an indicator of R&D internationalisation – is very heterogeneous. Most of these patents can be attributed to Germany (27.3 percent), the UK (18 percent) and France (14.3 percent), i.e. these countries attract the largest part of foreign R&D activities. Between 2001 and 2009, Germany managed to increase its share of such patents within the EU-27 by approximately 1.7 percentage points, whereas the UK and France lost percentage points (2.9 and 1.3 percentage points respectively). However, when examining the number of patent applications per 1 million inhabitants (as opposed to absolute numbers), an entirely different picture emerges: here, small countries such as the Netherlands, Belgium, Luxembourg and Sweden tend to score best in the patent application statistics.

Figure 6 shows the share of R&D activities of German and US companies in Europe as compared with other European and non-European companies. German enterprises are represented in numerous EU countries and make up a large part of foreign R&D activities in the respective countries. The share of German companies in foreign R&D expenditure is above 50 percent in Austria, above 30 percent in the Czech Republic and Hungary, and above 20 percent in Latvia, Slovakia and Denmark. It is also noteworthy that US companies are primarily represented in EU countries where German companies have made only minor R&D investments – and vice versa.

It can be generally observed that foreign direct investment will also result in R&D activities at a later stage. Hence a country's market size and revenue plays a key role in attracting foreign R&D.[258] In earlier studies, several factors have been identified that may be relevant to MNEs when choosing their R&D locations. To begin with, a country's industry structure and existing R&D activities play an important role: companies seek the proximity of other companies from the same industry and from other industries, which will enable intra-industry and inter-industry spillover effects. Thus existing private R&D investments in a potential new location are an important decisive factor for MNEs when choosing a location.[259] Another important factor is the quality of the local research system. When companies choose their R&D locations, academic research, collaborations with local universities and the supply of human capital are taken into account.[260] The protection of intellectual property rights is another important criterion for businesses in deciding for or against a location.[261] There is only weak evidence to confirm that lower labour costs facilitate the establishing of foreign R&D capacities,[262] whereas geographical proximity does indeed have a positive effect.[263]

A recent study examines the determinants of foreign R&D activity in the EU-27 countries on the basis of cross-border patents.[264] The study largely confirms findings from earlier studies. Thus it could be shown that a high proportion of a region's labour force working in scientific and technical careers encourages foreign R&D activities. This suggests that human capital is indeed an important factor for attracting foreign R&D. The study further confirms that private R&D expenditure and foreign R&D expenditure are positively linked, which suggests the existence of

FIG 06 **Important groups of investors in the EU target countries in 2007**



*Manufacturing only; **values for the year 2005. ***Germany included in rest of EU countries, United States included in other non-EU countries.
Source: *Europäische Kommission* (2012b).

knowledge spillover effects.[265] R&D tax benefits also have a positive effect on foreign R&D activities. If one examines the changes in tax rates over a longer period, there is evidence that higher statutory corporate tax rates are negatively linked with foreign R&D activities, which means that R&D activities decline as a consequence of an increase in tax rates.[266]

In terms of private R&D expenditure, Germany is relatively well-positioned when compared on a European level. Yet, when it comes to human capital, Germany displays deficits particularly with regard to its shortage of students in STEM subjects and engineering.[267] This is an area that requires further efforts if Germany is to strengthen its position in the international competition for R&D locations.

But also within a particular country, regions differ in terms of their attractiveness as R&D locations. In Germany, foreign R&D activities focus on the south and southwest of the country (cf. Figure 7), and this also applies to German patent applications.[268] The analysis of the determinants of foreign R&D activities in Germany[269] shows, again, that the existing industrial structure plays an important role. Thus, intra-industry and inter-industry spillover effects are important for a company's locational decision at regional level – just as they are at national level. The key role of the research system has also been confirmed in the regional analysis. Furthermore, a region's public education and science structure and sector-specific human capital have been identified as important decisive factors.

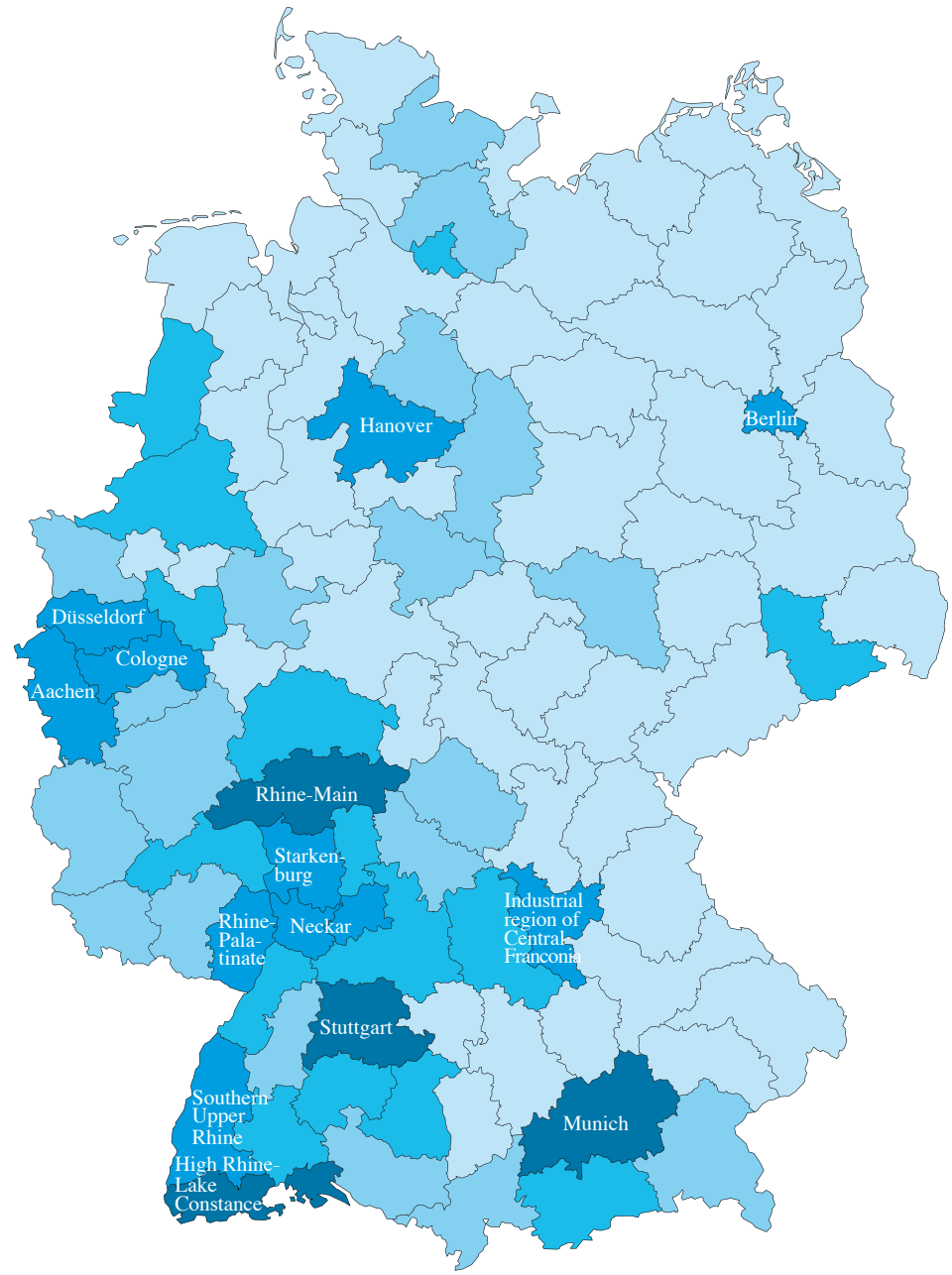
KNOWLEDGE FLOWS IN INTERNATIONAL R&D NETWORKS

B 2–5

The increasing importance of technological motives in the choice of international R&D sites demonstrates that MNEs can gain access to new knowledge by developing international R&D locations. A number of empirical studies have addressed the impact of foreign R&D investments on productivity and innovation activity of domestic companies that can result from technology transfer within an MNE or knowledge spillovers in the domestic economy.

Studies on German and British enterprises[270] have shown that companies with relatively strong R&D ties with the United States – as measured by the share of patents with inventors residing in the US – benefit disproportionately from R&D growth in the United States, when compared with less well-

Share of patent applications of foreign manufacturing enterprises in spatial planning regions, as measured by the total number of foreign patent applications in Germany in 2008 FIG 07



Source: own depiction based on IWH et al. (2013).

connected competitors. For UK-based companies, knowledge spillovers from foreign R&D investment to domestic corporations result in a productivity increase of 5 percent on average, while German companies benefit from a 15 percent productivity increase.[271] Moreover, it can be assumed that only some of the potential knowledge spillover effects can be documented by patent statistics. In addition, the statistics clearly indicate for German companies that close cooperation with US enterprises resulting in joint patent applications has a further positive effect on domestic productivity.

But a reverse transfer of technological know-how stemming from foreign R&D activities can also affect the local economy beyond corporate boundaries, provided that local companies are subjected to knowledge spillovers (an effect that is also known as inter-firm reverse technology transfer). Initial empirical studies have confirmed that the domestic economy can benefit from knowledge spillovers of MNEs with foreign R&D activities.[272] Based on patent citations, a study on European MNEs[273] has identified knowledge flows in the chemical and pharmaceutical industries between multinational corporations' foreign R&D activities in the US to domestic companies in Europe. Thus it could be shown that an MNE's integration in the home country – i.e. a close relationship with suppliers, clients, competitors and local universities – can foster investment in basic R&D. It could also been shown that such spillover effects increase in line with the differences in technological development between the home country and the United States.

Empirical evidence from individual country studies suggests that, under certain circumstances and in certain industries, the international relocation of R&D activities can be beneficial to MNEs in their home country as well as to domestic businesses in the form of knowledge spillovers. Foreign R&D activities provide options for letting domestic corporations and local companies benefit from knowledge created abroad. As a general rule, it can be assumed that potential spillover effects are strongest when stemming from foreign R&D knowledge transfer of technologically advanced countries such as the United States.

NEW CHALLENGES FOR THE RESEARCH AND INNOVATION POLICY IN GERMANY B 2–6

The globalisation of research and innovation urges us to reconsider the scope of national and European innovation policies. The analysis of the development of international R&D locations has shown that there is an ever increasing international division of labour. Companies are highly mobile in their choice of R&D locations and consciously choose sites that enable them to benefit from local know-how. German enterprises that have considerably increased their foreign R&D expenditure primarily belong to the pharmaceutical, automotive and chemical industries, as well as computing, electronics and optics. Foreign enterprises that are present in Germany with their own R&D capacities primarily belong to the automotive, chemical and pharmaceutical industries, as well as mechanical and electrical engineering and computer manufacturing.

For Germany as a research and innovation location, this entails opportunities and threats, which will have to be adequately addressed by national research, innovation and education policies. R&D activities of foreign companies in Germany strengthen Germany's position as a centre of innovation in the areas mentioned above, while also creating attractive employment opportunities for researchers in Germany. Furthermore, the increasing shift of R&D in key areas of cutting-edge technology to locations abroad poses a particular challenge for Germany as an R&D location.

In view of the high specialisation of German companies in certain fields of technology, and in view of the streamlined concentration of foreign MNEs' R&D activities in Germany, the Expert Commission strongly recommends designing educational and basic research policies on a broad-based approach so as to prepare for future technological developments. At the same time, the foundations for the future use of newly created knowledge will have to be laid by means of efficient technology transfer.

To ensure that R&D in cutting-edge technology is conducted in Germany, it is essential to retain strong application-oriented public research institutions in Germany and to attract foreign MNEs that will expand their R&D capacities, while also closely collaborating with domestic research organisations.

Restraint should be exercised in the funding of applied research activities by German public research organisations abroad. Obstacles for foreign enterprises participating in support measures, such as cluster programmes and the Research Campus, should be removed. An effective promotion of applied research in Germany can contribute to making Germany a more attractive partner for companies from abroad.

Germany will be able to achieve the high level of R&D intensity targeted only if cutting-edge technologies and knowledge-intensive services are expanded. To accomplish this, it will be increasingly necessary to attract further investment from foreign MNEs in Germany. Reliable financial and fiscal framework conditions play a crucial role for the investment decisions of MNEs. Germany is one of the few countries that still does not offer R&D tax credits. If Germany is not to fall behind in international competition, this tax-related locational disadvantage will have to be corrected by means of implementing R&D tax credits. It is imperative that these measures be introduced at the beginning of the next legislative term.

In addition, decision-makers from politics and science should engage in a regular, systematic exchange with research-intensive companies from abroad. The foreign R&D activities of German companies are also the topic of the federal government's dialogue with decision-makers from industry and academia. The Federal Chancellor's Innovation Dialogue, held in late 2012, was titled "Innovation Strategy Asia". In the coming years, the Innovation Dialogue should discuss strategic locations and the innovation strategies of selected countries and their implications for Germany. Moreover, Germany's large companies with R&D facilities abroad are also members of the high-level Research Union. The Research Union could provide a platform for addressing the issue of balancing foreign and domestic R&D. The Federal Government engages in regular intergovernmental consultations with several countries (e.g. the US and China) in the context of which innovation and education policies are also discussed. For instance, bilateral innovation policy platforms have been established with China and the United States, which also serve to address the balancing of bidirectional foreign R&D investment.[274] The Federal Government and the federal ministries have implemented dedicated internationalisation strategies. These measures could initiate projects and developments that are mutually beneficial.

In view of the increasing importance of R&D internationalisation, it is paramount to improve the available data and academic research on transnational R&D processes. Especially the database relating to R&D expenditure and key activities of German companies abroad is very patchy and stems from multiple institutions. The *Deutsche Bundesbank,* the *SV Wissenschaftsstatistik* and other existing research institutions should link their databases based on the example of the annual publications of the Bureau of Economic Analysis (BEA) in the United States. Such an approach would greatly benefit innovation policy in Germany.