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Article

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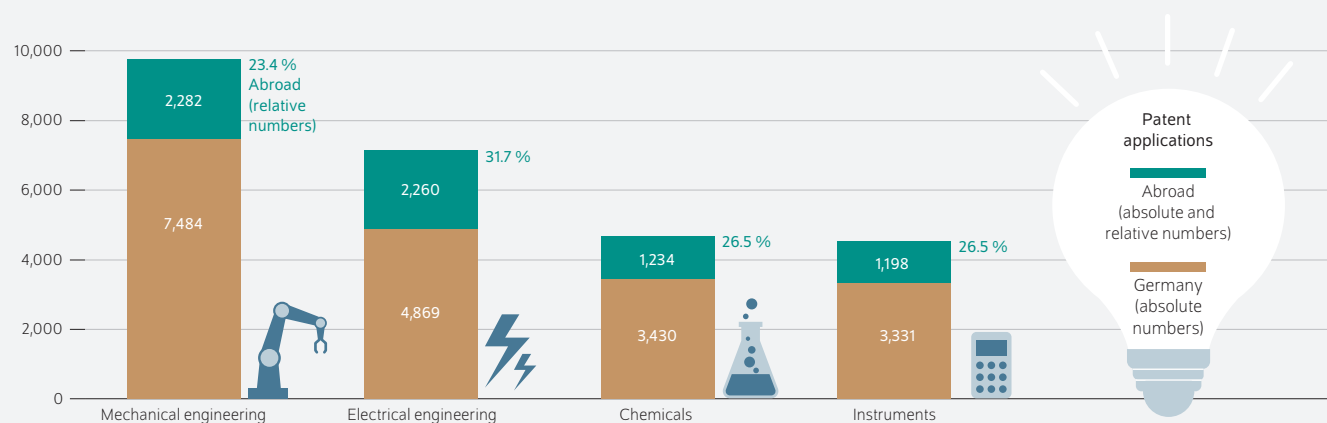
AT A GLANCE

Research and development abroad: German companies focus on strengths similar to those at home

By Heike Belitz, Anna Lejpras, and Maximilian Priem

- Based on patent data, the study examined the extent and orientation of German companies' R&D activities abroad
- More than one in four patents that German companies apply for is based on inventions from their research laboratories abroad
- In most cases, companies' activities abroad supplement and enhance the knowledge they acquired at home; supporting market development is a second motive
- Germany does not sacrifice its own importance as a research location due to the international R&D activities of German companies; no indication of "relocation"
- However, deficits in new digitalization technologies must increasingly be compensated for abroad; research in this field should be strengthened in Germany

German companies' foreign R&D focuses on technological areas in which they make many inventions domestically



Sources: Institute for Prospective Technological Studies and OECD Directorate for Science, Technology and Innovation (EC-JRC/OECD COR&DIP® database, v.1. 2017); Europäisches Patentamt (PATSTAT v5.11); authors' own calculations.

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FROM THE AUTHORS

"The performance of domestic R&D still largely determines the innovative strength of German companies operating globally. Germany is not losing any importance as a research location as a result of international activities; although relocation is a fear, there are hardly any indications of it occurring."

— Heike Belitz —

DATA

Data on the **104 companies strongest in research in Germany** and on 1,564 competitors worldwide were evaluated.

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ABSTRACT

More than one in four patents that major German companies apply for is based on inventions from their research laboratories abroad. In three quarters of the cases, the companies have focused on technologies in which they are very strong at home. Therefore, to a great extent the technological research and development performance at their home location determines the innovative power of globally active German companies. As the present report also shows, based on patent data, most foreign research activities abroad either supplement domestic activities or support sales and production abroad. Internationalization strategies intended to compensate for technological deficits at home have a lower proportion. German companies in the information and communication technology industries, whose importance is increasing in the wake of digitalization, are the primary implementers of such strategies. To better be able to acquire and use the knowledge companies gain abroad, the research in these technological fields of the future should be strengthened in Germany as well. As a research location, Germany can benefit from the continuing internationalization of its globally active companies if public research, at universities for example, can expand their technological basis and remain attractive cooperation partners to said companies.

When German companies carry out research and development (R&D) abroad, many interpret it as a loss for the domestic location.¹ From the company's point of view, it is useful to develop their products and processes further in foreign target markets, adapting them to local conditions and customer requirements. Setting up company research laboratories abroad can also serve the purpose of studying the new technological knowledge of local competitors, universities, and research institutes, or developing new products and processes in the local laboratory. After all, acquiring the know-how of research personnel in the host country is a key motive for R&D abroad.²

The German Institute for Economic Research (DIW Berlin) and DIW Econ³ studied the scope and technological orientation of the R&D activities of German companies at home and abroad for the Hans Böckler Foundation.⁴ For 104 top German R&D investing companies information on the focal areas of technological research they carry out at home and in various host countries abroad was acquired from patent data. The study encompassed the period from 2012 until 2014 (see Box 1). The technological and regional distribution of the R&D activities of German companies at home and abroad provides an indication of the motives for their internationalization. Was it driven by the desire to acquire new technological knowledge or by customer requirements

¹ For example, Peter Bofinger, a member of the German Council of Economic Experts, described examples of German companies such as Siemens, Bosch, and Schaeffler setting up application-oriented research facilities in China as relocation. He views their activity as confirmation of the hypothesis according to which companies relocate their R&D activities to countries that can offer better R&D infrastructures and more beneficial financial support. See German Council of Economic Experts, "Setting the Right Course for Economic Policy," *Annual Report 2018/2019*, 79 (2018) (available online, accessed August 21, 2019; this applies to all other online sources in this report unless stated otherwise)

² Among others, see Walter Kuemmerle, "Building effective R&D capabilities abroad," *Harvard Business Review*, March–April, (1997): 61–70; Parimal Patel and Modesto Vega, "Patterns of internationalisation of corporate technology: location vs. home country advantages," *Research Policy*, 28, (1999): 145–155; United Nations Conference on Trade and Development, *World Investment Report: Transnational corporations and the internationalisation of R&D* (2005) (available online); and Organisation for Economic Co-operation and Development, *The Internationalisation of Business R&D: Evidence, Impacts and Implications* (2008).

³ DIW Econ is the DIW Berlin subsidiary for economic consulting.

⁴ Heike Belitz, Anna Lejpras, Anselm Mattes and Maximilian Priem, "Forschung deutscher Unternehmen im In- und Ausland, Technologische Schwerpunkte und Zielregionen," *Working Paper der Forschungsförderung der Hans-Böckler-Stiftung*, 156, (2019) (available online).

and conditions in the target market? Are the companies enhancing their knowledge abroad in the technologies in which they have a domestic advantage in their research laboratories? Or are they involved with technologies they need to catch up on, and as a result, have to carry out research at foreign locations?

Every fourth inventor for German companies works abroad

Among the 2,000 companies strongest in research worldwide in the period from 2012 until 2014, there are 114 German companies. They are responsible for 11 percent of global R&D expenditure. In 2014, that amounted to a solid 62 billion euros, approximately as much as the total R&D expenditure of all companies in Germany.⁵ A total of 1,668 of the companies that are worldwide research leaders applied for patents. Among them were 104 companies from Germany, with a share of eight percent in all patents.

The foreign proportion of inventions by German companies was 27 percent during the study horizon of 2012-2014 (see Table 1). Around one in four inventors from German companies works abroad. The foreign proportion of R&D expenditure was 31 percent in 2013.⁶ Thus, R&D carried out abroad leads to patents to the same extent as R&D done in Germany does. And the originality and quality of corporate research abroad are not significantly lower than that of the research done in Germany.

Altogether, the research-intensive industries transport equipment, mechanical engineering, data processing, electronics, optics, as well as the chemical and pharmaceutical industries are responsible for three quarters of the total worldwide inventions of German companies. German companies in the transport equipment industry have registered the most inventions (29 percent), followed by mechanical engineering (around 19 percent), data processing, electronics, and optics (12 percent, see Table 1). While transport equipment companies only developed one in five inventions abroad, the pharmaceutical industry's proportion is 36 percent.

These inventions are concentrated in only a few companies. Only six large companies applied for one half of all patents of the 104 German companies, and among those with inventors abroad the proportion jumps to 60 percent (see Table 2). Among the six top patenting German companies, the share of inventions developed abroad varies greatly. At 44 percent, Infineon has the largest share of foreign inventions and at 19 percent, the share at Volkswagen is less than half of the size.

⁵ The R&D expenditure of all companies in Germany (internal and external R&D expenditure outside the economic sector) was just under 67 billion euros in 2015. See SV Wissenschaftsstatistik, *ö.r.än 'di: Zahlenwerk 2017, Forschung und Entwicklung in der Wirtschaft 2015*, (2017).

⁶ See SV Wissenschaftsstatistik, *ö.r.än 'di: Zahlenwerk 2015, Forschung und Entwicklung in der Wirtschaft 2013*, (2015).

Box 1

Data

For the company-specific analysis of worldwide R&D and patent activities of the 104 German research leaders by technological field and target country, two data sets were combined.

One data set contains information on the R&D expenditure and patent applications of the 2,000 global research leaders between 2012 and 2014 (EC-JRC/OECD COR&DIP© database, v.1. 2017 of the EC-JRC Institute for Prospective Technological Studies and the OECD Directorate for Science, Technology and Innovation), and the other is the

Patent database of the European Patent Office with bibliographical data on patents (EPO Worldwide Patent Statistical Database PATSTAT, spring 2018).

To avoid double counting inventions with multiple patent applications at multiple patent offices, the evaluation was carried out on the "patent family" level. Here, patent families summarize an invention's various patent applications to the world's five largest patent offices. The technological orientation of the R&D activities that support the invention was mapped based on 35 technological fields.¹ The place of invention for a patent family is equal to the inventor's place of residence. Since one invention mapped in a patent family can be allocated to several inventors at different places, several patents, several applying companies, and several technological fields, the patent families were weighted using a fractional counting method.

¹ Ulrich Schmoch, "Concept of a Technology Classification for Country Comparisons. Final Report to the World Intellectual Property Organisation (WIPO)," 2008.

This is also a function of the different proportion of foreign invention in individual technological fields, which varies between 15 percent in handling and logistics and 48 percent in data processing. Some technological fields that have only minor importance to the German research leaders have particularly high proportions of foreign invention, including: IT methods for management, basic communication technology, biotechnology, food chemistry, and biological materials analysis (see Figure 1).

U.S., Austria, and France are the most important foreign research locations

Inventors in companies headquartered in Germany are located worldwide and are little regionally concentrated. Their distribution among the host countries is an approximate reflection of the distribution of R&D expenditures

Table 1

Worldwide R&D expenditures and patent applications of German companies for industries, 2012 to 2014
Percentage shares

	R&D expenditure	Weighted patent applications	Foreign share
Manufacturing	86.5	88.7	–
Thereunder from:			
Chemical Industry	5.9	9.8	29
Pharmaceutical industry	13.9	5.4	36
Rubber, plastics, minerals	3.6	4.9	36
Computers, electronics, optics	3.2	12.2	32
Electrical equipment	1.6	3.3	24
Mechanical engineering	10.0	18.5	30
Transport equipment	45.7	29.2	20
Other industries	13.5	11.3	–
Thereunder from:			
Wholesale, retail, repairs	2.2	3.0	16
Professional, scientific, and technical activities	2.5	5.2	29
Total	100.0	100.0	27

Sources: Institute for Prospective Technological Studies und OECD Directorate for Science, Technology and Innovation (EC-JRC/OECD COR&DIP© database, v.1. 2017); Europäisches Patentamt (PATSTAT v5.11); authors' own calculations.

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Table 2

Patent applications of the six top patenting German companies at home and abroad, 2012 to 2014
In percent

Company	Weighted patent applications of German companies			
	Worldwide	In Germany	Abroad	Foreign share
Bosch	17.2	17.9	15.4	23.8
Siemens	11.6	9.6	17.2	39.3
Infineon	7.2	5.5	12.0	44.2
Volkswagen	7.2	7.9	5.2	19.3
Continental	4.8	4.1	6.5	36.4
BASF	4.2	3.5	6.1	39.0
Total	52.2	48.5	62.4	–

Sources: Institute for Prospective Technological Studies und OECD Directorate for Science, Technology and Innovation (EC-JRC/OECD COR&DIP© database, v.1. 2017); Europäisches Patentamt (PATSTAT v5.11); authors' own calculations.

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abroad.⁷ The two key research regions for German companies abroad are the European Union and the U.S., with proportions of worldwide inventions of 12 and nine percent respectively between 2012 and 2014 (see Figure 2). By a clear margin, Asia comes next (five percent). In Europe, neighbors Austria at 3.4 percent and France at 1.8 percent are the largest host countries for the R&D of German companies. At 1.5 percent, China ranks number four. India and Eastern European countries, which have at times been reputed to be important locations for German companies, have very small proportions of patent applications.

⁷ For 17 host countries for the R&D of German companies, primarily in Europe, the national statistics also contain information on the companies from Germany in the country. With a correlation coefficient of 0.984, the correlation between the R&D expenditure in 2015 and the weighted inventions of German companies in the period between 2012 and 2014 in those countries is very close. See Belitz, Lejpras, Mattes and Priem, "Forschung deutscher Unternehmen im In- und Ausland."

In the technological categories of electrical engineering and mechanical engineering, the EU is the most important foreign research region, followed by the U.S. (see Figure 3). They are also the world's key location for R&D in chemical technology. In Asia, R&D activity in the field of electrical engineering clearly predominates.

Similar technological specialization at home and abroad

To find out the technological fields in which the companies have strengths and weaknesses, a revealed technological advantage index (RTA) was calculated using patent data (see Box 2). According to the RTA, in comparison to their competitors, globally active German companies are specialized in the "classic German" technological fields, which include

mechanical engineering (of which automotive engineering is a part), chemicals, and pharmaceuticals. On the contrary, in the entire area of electrical engineering, which includes information and communication technology, they are at a specialization disadvantage (see Figure 4).

Whether at home or abroad, German companies generally concentrate on the same technological fields. The relatively small fields of biotechnology and food chemistry are exceptions in which German companies only specialize abroad. They are at a specialization disadvantage in Germany in basic communication technology and IT methods for management, but this disappears when looking at research abroad.

Patent information can be used to examine which strategies German companies follow with their R&D activities abroad. In other words, it is possible to find out whether or not they research the technologies in which the host countries have technological advantages: in a global comparison, those in which they are highly specialized. This would indicate that in these countries, German companies are primarily searching for technological knowledge that is not available to them at home. If, on the other hand, they research in technological fields in which the host countries are not specialized (in which they do not have a distinct knowledge base), we can conclude that they are driven by market-related motives.

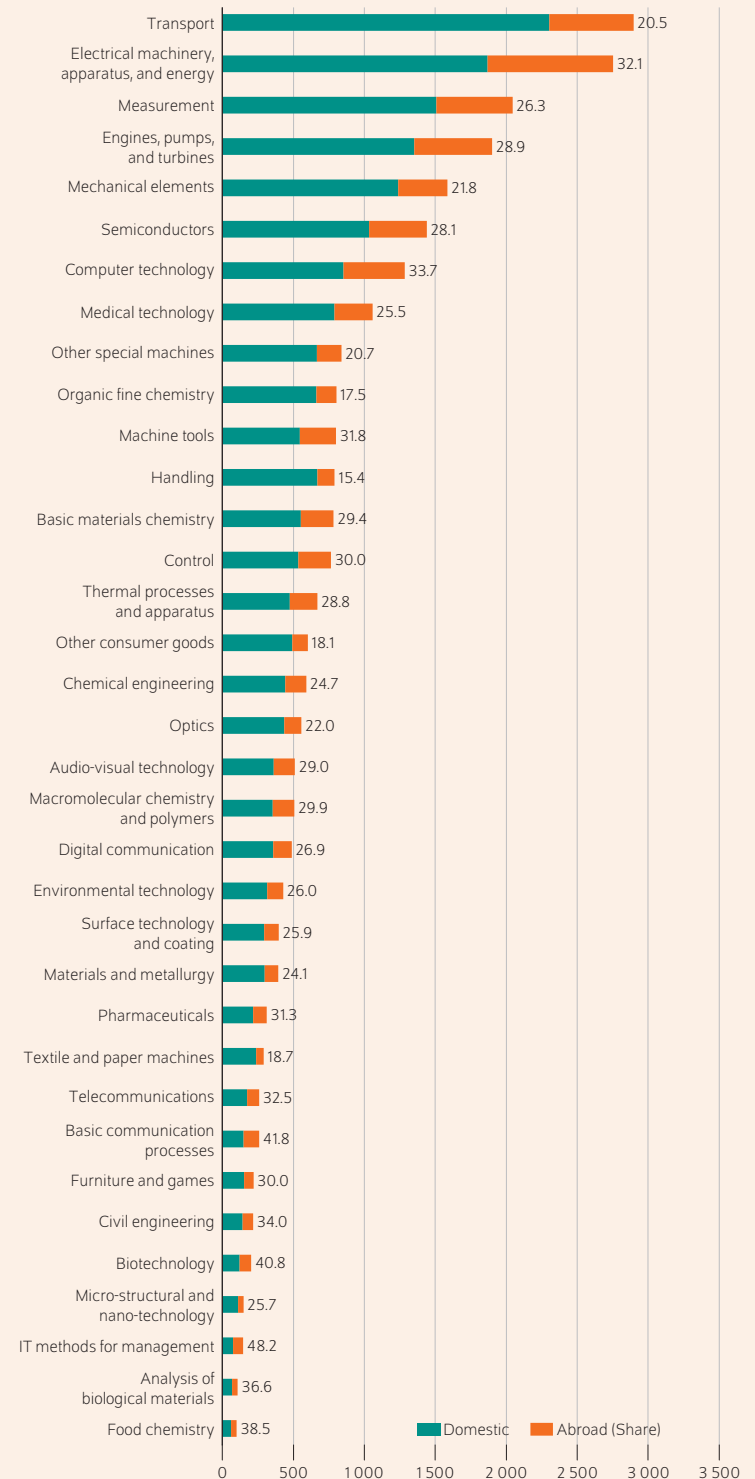
To characterize the internationalization strategy of German companies by technology and host country, we used the same classification scheme that the patent portfolios of the companies use. It has also been applied several times in the literature.⁸ The strategies of the companies in the respective target region were identified based on two measures of technological advantage (see Box 2).

In order to determine the level of a company's technological advantage in its home country (*RTA home*), we found the relationship between two proportions, first, the proportion of a company's patent applications that were researched abroad in relation to all of the company's patent applications and second, the proportion of all patent applications from companies in this technological field in relation to all patents worldwide.

In order to determine the level of a company's technological advantage in its host country or region (*RTA host*), we also found the relationship between two proportions, first, the proportion of all patent applications of all companies that research in a specific technological field in relation to all patent applications in the host country and second, the proportion of patents applied for worldwide in this technological field in relation to all patents.

Figure 1

Patent applications of German companies at home and abroad by technological fields, 2012 to 2014



Sources: Institute for Prospective Technological Studies und OECD Directorate for Science, Technology and Innovation (EC-JRC/OECD COR&DIP© database, v.1. 2017); Europäisches Patentamt (PATSTAT v5.11); authors' own calculations.

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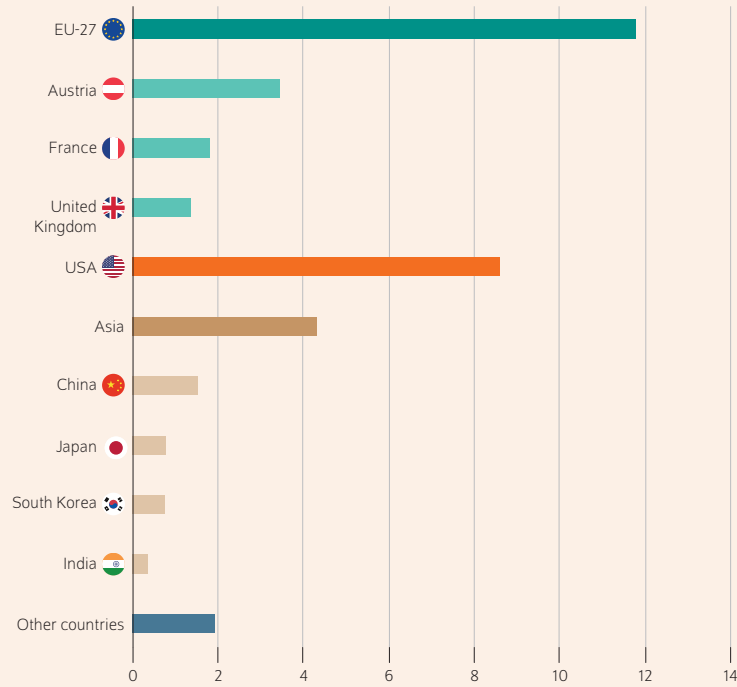
Over all technological fields, the foreign share of inventions varies between 15 percent in handling and 48 percent in IT methods for management.

⁸ See Parimal Patel and Modesto Vega, "Patterns of internationalisation"; and Christian Le Bas and Christophe Sierra, "Location versus home country advantages in R&D activities: some further results on multinationals' locational strategies," *Research Policy*, 31 (2002): 589–609.

Figure 2

Worldwide patent applications of German companies by regions and countries, 2012 to 2014

Percentage shares of weighted patent applications



Sources: Institute for Prospective Technological Studies und OECD Directorate for Science, Technology and Innovation (EC-JRC/OECD COR&DIP© database, v.1. 2017); Europäisches Patentamt (PATSTAT v5.11); authors' own calculations.

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The major research host regions for German companies are other EU member states and the USA.

Depending on the level of the two measures of specialization, we were able to describe four internationalization strategies for a technological field in a foreign target region (see Table 3).

In the home-base augmenting, the company is strong in the relevant technological field at home and also has advantages in the host country. The company is using its complementary strengths abroad to build and add to the technological strengths it has developed at home.

In the home-base exploiting strategy, research is relatively weak in the host country and the company is applying the technological advantages it acquired at home there. This means that abroad, the company is seeking technical support for its sales and foreign production.

By following a technology-seeking strategy, the company is trying to compensate for its technological weakness at home by carrying out research in countries that are strong in those fields. In this way, research at top locations can open up access to new high technologies for them.

In the market-seeking strategy, technological motives do not play an important role because neither the company's home country nor the host country are specialized in the relevant field of research. Research abroad could be the result of a corporate takeover motivated by reasons that have little to do with technology.

Home-base augmenting internationalization strategy predominates

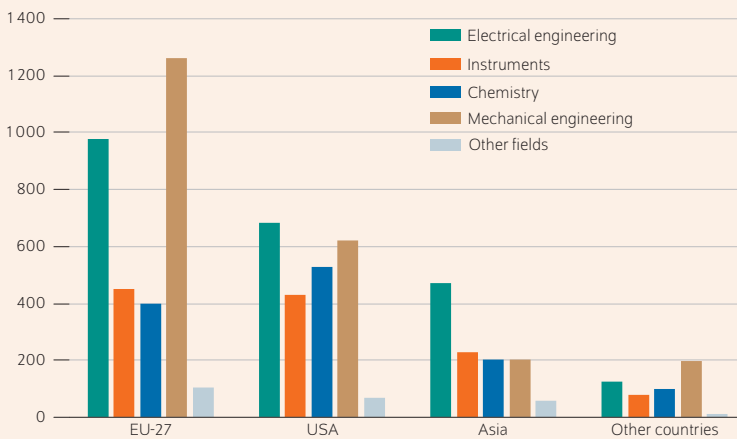
The home-base augmenting strategy predominates in internationalization: just under 50 percent of invention activity abroad falls into this classification (see Table 4). A further one-quarter of the activity can be attributed to the home-base exploiting strategy. Thus, three-quarters of the R&D activities of German companies abroad take place in research fields, in which by international comparison the companies have technological specialization advantages in their home country.⁹ In most cases, research abroad is based on the technological strengths of research in Germany.

Only 12 percent of patents abroad indicate a technology-seeking strategy in which the company carries out research abroad in fields in which it is not specialized in a host country that does have technological advantages. We can assume that companies pursue this strategy in order to acquire new technological knowledge at top foreign research locations. With above-average frequency, companies from Germany follow the technology-seeking strategy in the computer technology, optics, data processing, and digital communication

Figure 3

Patent applications of German companies abroad by technology areas, 2012 to 2014

Weighted patent applications in absolute numbers



Sources: Institute for Prospective Technological Studies und OECD Directorate for Science, Technology and Innovation (EC-JRC/OECD COR&DIP© database, v.1. 2017); Europäisches Patentamt (PATSTAT v5.11); authors' own calculations.

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Mechanical and electrical engineering are the dominant technological categories for R&D activities of German companies in other EU member states.

⁹ In comparison with an older study of 87 German companies, the proportion of the two strategies has remained approximately the same since the mid-1990s. However, the proportion of the knowledge-building strategy has become somewhat higher than that of the knowledge-using strategy. See Patricia Laurens et al., "Internationalisation of European MNCs R&D," *Management international*, 19(4) (2015): 18–33.

technological fields. This strategy is rarely used in the technological fields of mechanical engineering and chemicals.

While electrical engineering companies follow all four internationalization strategies to a similar extent, the clear focus in mechanical engineering, chemicals, and instrument technology is the home-base augmenting strategy in which the company is specialized in the relevant technologies both at home and in the host countries. Companies that follow this strategy are combining the technological advantages of the company at home with the relevant technological advantages abroad.

An above-average share of German companies follow technology-seeking strategies in the U.S., Austria, Denmark, and South Korea – all extremely research-intensive countries. German companies tend to carry out the home-base augmenting strategy in neighboring European countries. Most research in China is clearly following the home-base exploiting strategy, which primarily aids in adapting products and processes to the conditions in the target country.

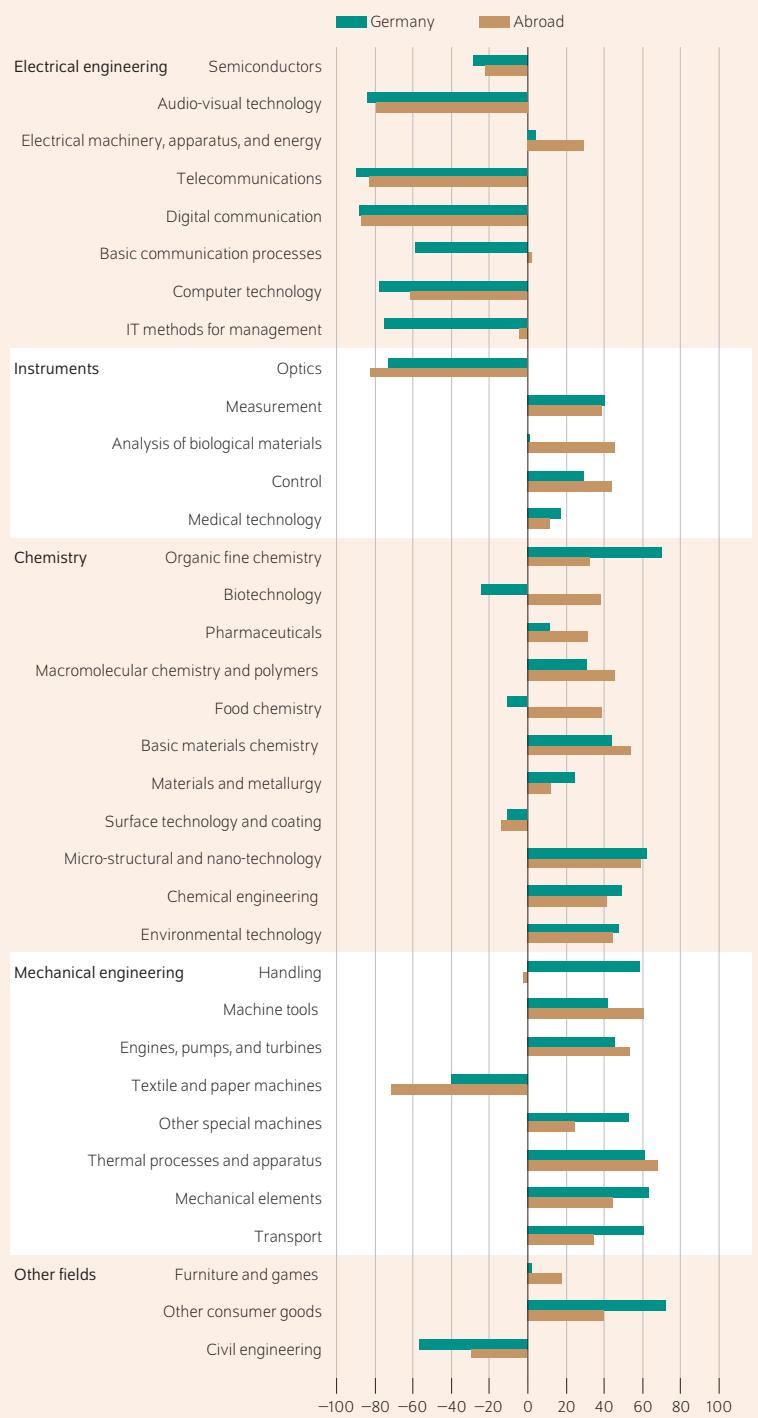
And the six German companies with the largest number of patent applications primarily follow the home-base augmenting strategy. Obvious differences are apparent in the significance of the technology-seeking strategy. At BASF, Siemens, and Infineon, it has a share of approximately 20 percent – significantly higher than the average of all companies. Bosch has an above-average proportion with regard to the home-base exploiting internationalization strategy, meaning that it researches abroad in many technologies to support its sales and local production.

Conclusion: Research abroad supports technological strengths in Germany but also reveals deficits in digitalization technology

Although a solid 25 percent of the inventions of globally active German companies are developed abroad, most of their innovative power is still determined by their R&D performance in locations at home: companies from Germany typically carry out research abroad from a position of technological strength at home. In Germany’s high-performance focal areas of research – mechanical engineering, chemicals, and measurement and control technology – company research activities abroad supplement and enhance the knowledge developed at home. Another key motive is using the domestic knowledge advantage to adapt process and products to conditions and customer requirements abroad.

As a research location, Germany does not sacrifice any technological strength as a result of its companies’ international activities. Research that is carried out in addition to technological activities at home or to support market development is not an indication of “relocation.” Actually, German companies use some internationalization strategies to compensate for their technological deficits at home. They are not very significant in relative terms, but companies follow them for technologies whose importance is increasing within the

Figure 4
Technological specialization (RTA) of German companies at home and abroad, 2012 to 2014



Sources: Institute for Prospective Technological Studies und OECD Directorate for Science, Technology and Innovation (EC-JRC/OECD COR&DIP© database, v.1. 2017); Europäisches Patentamt (PATSTAT v5.11); authors' own calculations.

Overall, German companies have specialized in the technological areas mechanical engineering and chemistry.

Kasten 2

Revealed technological advantage index (RTA)

In order to determine the technological fields in which individual companies or corporate groups have specialized by country or region, we used the revealed technological advantage index (RTA). It was originally used to measure international trade specialization but was soon applied to quantifying technological advantage based on patent data.¹ The RTA index measures the relative concentration of invention activity (patent families *p*) of a company on specific technologies in comparison to a population of companies. It is defined as follows:

$$RTA_{tr} = (p_{tr} / \sum_i p_{ir}) / (\sum_i p_{tr} / \sum_{ir} p_{ir})$$

In the equation, *t* stands for the technological field's index and *r* for the index of the respective company. To classify the internationalization strategies, the technological advantage of an individual company at home (RTA home) and the technological advantage of all the companies in a target country (RTA target) were measured.

¹ Keld Laursen, "Revealed comparative advantage and the alternatives as measures of international specialization," *ILR Review* 5 (2015): 99–115.

Since the RTA scale runs from 0 to infinity and is difficult to interpret intuitively, it was transformed as follows:

$$RTA_{mod, r} = 100 \times \tanh \ln(RTA_{tr})$$

By converting the RTA with the hyperbolic tangent of the original RTA's logarithm, the RTA becomes a symmetrical measure with values between -100 and +100.

A value of 0 means that the proportion of a technological field in the particular company equals the average proportion of the field in all companies. The index assumes a negative value (maximum -100) when the proportion of patent applications by the examined company in the technological field under observation is smaller than the proportion in all companies, indicating that the company has no advantage. Positive values (maximum +100) show an above-average proportion of patents in these fields and therefore, reveal a company's technological advantage in the relevant technological field.

context of digitalization: computer technology, IT methods for management, and digital communication technology. These research fields must also be strengthened in Germany

in order to improve the way knowledge acquired abroad is integrated into the home location and pave the way for leveraging innovations at home.

Table 3

Internationalization strategies of companies R&D

Technological Specialization		...of host countries	
		strong	weak
...of companies at home	strong	(1) home-base augmenting HomeRTA > 0 HostRTA > 0	(2) home-base exploiting HomeRTA > 0 HostRTA < 0
		(3) technology-seeking HomeRTA < 0 HostRTA > 0	(4) market-seeking HomeRTA < 0 HostRTA < 0

1 Revealed technological advantage (RTA), see box 2 in this report

Sources: Compiled by the authors on the basis of Christian Le Bas and Christophe Sierra (2002): Location versus home country advantages in R&D activities: some further results on multinationals' locational strategies. Research Policy, 31.

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Table 4

Internationalization strategies of German companies by technological category, host country, and six top patenting German companies, 2012 to 2014

Percentage shares

	Internationalization strategies				Total
	Home-base augmenting	Home-base exploiting	Technology-seeking	Market-seeking	
Total	50	27	12	11	100
Technological area:					
Electrical engineering	31	26	18	25	100
Instruments	61	20	14	5	100
Chemistry	57	29	9	5	100
Mechanical engineering	60	28	6	6	100
Other fields	37	42	16	5	100
Host country:					
USA	47	26	16	11	100
Austria	54	15	14	17	100
France	61	24	4	11	100
China	12	79	5	5	100
United Kingdom	50	22	6	22	100
Sweden	63	27	2	8	100
Italy	67	11	8	14	100
Swiss	56	25	8	11	100
Denmark	50	21	20	9	100
Japan	41	47	9	3	100
South Korea	27	29	36	8	100
Other country	56	22	12	10	100
Company:					
Siemens	43	27	19	12	100
Bosch	45	39	8	9	100
Infineon	53	5	19	23	100
Volkswagen	59	21	6	14	100
Continental	55	16	11	18	100
BASF	42	28	20	11	100

Sources: Institute for Prospective Technological Studies und OECD Directorate for Science, Technology and Innovation (EC-JRC/OECD COR&DIP© database, v.1. 2017); Europäisches Patentamt (PATSTAT v5.11); authors' own calculations.

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