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Research and Development in manufacturing: companies performing better than ever

By Alexander Eickelpasch

In 2008 and 2009, during the economic crisis, Germany's industrial enterprises invested considerably less in research and development (R&D). From 2010 to 2013, investments increased markedly again by an annual growth rate of 6.8 percent. This increase can be partly traced back to the process of catching-up after the crisis. Considering the period 2008 to 2013 research expenditures increased by annually 3.2 percent. Spending related to added value also increased. The research-intensive sectors were primarily responsible for these increases. The larger firms with 250 or more employees expanded their R&D spending considerably, while small and medium-sized enterprises (20 to 249 employees) reduced investment slightly – possibly also because higher government R&D funding during the crisis was scaled back after 2012. Consequently, R&D spending has not increased across the board. Overall, however, manufacturing in Germany is heading in the right direction with strong R&D growth putting it on a more solid footing than in other European countries.

Industrial production collapsed dramatically during the global economic and financial crisis of 2008 and 2009 but then recovered quickly. The level of industrial added value (price-adjusted) in 2011 was already above the 2007 level. It is therefore continuing its course of expansion which began in the mid-2000s. Studies published to date examining the research and development activities of industrial enterprises, an essential prerequisite for future growth, since the crisis have not gone beyond 2010. They show that companies reduced their R&D spending and R&D personnel less than production.¹ Studies that, in contrast to the present report, not only include R&D spending but also total innovation spending² show a more significant decline during the crisis³ and strong growth in 2012 and 2013.⁴

The data basis of this report is the cost structure survey in manufacturing, mining and quarrying, and earthworks (*Kostenstrukturserhebung im Verarbeitenden Gewerbe sowie des Bergbaus und der Gewinnung von Steinen und Erden, KSE*) conducted by Germany's Federal Statistical Office. The statistics captured annually since 1999 include, among other things, the number of R&D employees and in-house R&D spending (personnel, material costs, and investments) by the com-

¹ A. Kladobra and G. Stenke, "Wie krisenfest ist Forschung und Entwicklung? Auswirkungen der Wirtschafts- und Finanzkrise 2009 auf die FuE-Aktivitäten der deutschen Wirtschaft," in A. Kritikos and A. Konrad, "Der Forschungsstandort Deutschland nach der Krise," *Vierteljahrshefte zur Wirtschaftsforschung* 3, no. 80 (Berlin: 2011): 55-71; A. Eickelpasch, "Research-Based Companies Perform Better," *DIW Economic Bulletin* 10 (2012).

² Innovation spending not only includes internal and external spending on research and development but also investment in tangible and intangible assets, construction costs, design, product design, conception, initial and further training, market launch, and other preparations for the production and distribution of innovations. See C. Rammer et al., *Innovationsverhalten der deutschen Wirtschaft Indikatorenbericht zur Innovationserhebung 2014* (Mannheim: 2015), 3.

³ C. Rammer, "Auswirkungen der Wirtschaftskrise auf die Innovationstätigkeit der Unternehmen in Deutschland," in A. Kritikos and A. Konrad, "Der Forschungsstandort Deutschland nach der Krise," *Vierteljahrshefte zur Wirtschaftsforschung* 3, no. 80 (Berlin:2011): 13-33.

⁴ Rammer et al., *Innovationsverhalten*, 3.

pany.⁵ The *KSE* is a sample survey, the results of which are extrapolated. In 2013, the sample included almost 18,000 companies, i.e., 45 percent of the total. A sample is taken from the group of companies with up to 499 employees while data from companies with 500 or more employees are recorded in full. Very small industrial enterprises with 20 employees or fewer and contract research are not included. Another shortcoming is that only the number of R&D employees is captured and not their working hours. *KSE* provides information on the development and importance of research-based companies and allows comparisons with non-research-based companies.⁶

The following statements are based on special analyses by the Federal Statistical Office for the manufacturing sector (excluding mining) for the reporting years 1999 to 2013. This allows the development before, during, and after the crisis years of 2008 and 2009 to be examined. The years 2004 to 2007 are defined here as pre-crisis. However, the time series cannot be applied because the Federal Statistical Office has used the new classification of economic activities since 2008.⁷ Since then, some sectors have no longer been included in the manufacturing sector and, within the industry, the classification of individual branches has also changed. However, the differences are not particularly important in terms of manufacturing as a whole.

R&D spending and personnel increased considerably after the crisis

In 2013, Germany's industrial enterprises spent a total of 57.2 billion euros on in-house research and development. This amount includes personnel and material costs as well as investments in R&D. During the eco-

⁵ The survey concept follows the internationally binding definitions and boundaries documented in the OECD's Frascati Manual. See OECD, *Frascati Manual. Proposed Standard Practice for Surveys on Research and Experimental Development* (Paris: 2002). The *KSE* also captures data on production and sales, costs and cost categories, and the number of employees.

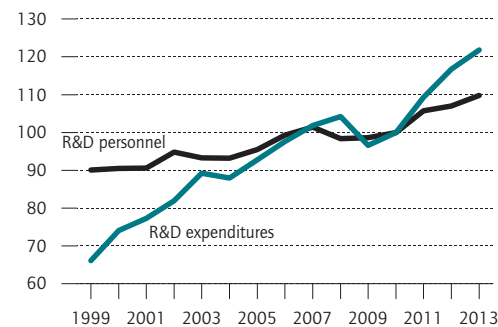
⁶ The R&D survey conducted by *Wissenschaftsstatistik GmbH* of the Donors' Association for German Science (*Stifterverband für die Deutsche Wissenschaft, SV*) provides detailed information on R&D. However, it does not allow a comparison with non-research-based companies. The *KSE* data are not fully comparable with those of the Donors' Association, partly due to the different definitions used by the reporting units and the different survey methods (H. Haug and C. Revermann, "Statistik für Forschung und experimentelle Entwicklung im Vergleich," in *Wirtschaft und Statistik* 12 (2003):1130-1136; U. Schasse, "Forschung und Entwicklung in Staat und Wirtschaft," *Studien zum deutschen Innovationssystem* 3 (Hanover and Essen: 2015) and the Expert Commission on Research and Innovation, *Gutachten zu Forschung, Innovation und technologischer Leistungsfähigkeit Deutschlands 2015* (Berlin: 2015), 23ff). In addition, participation in the *KSE* is mandatory while participation in the R&D survey is voluntary.

⁷ Federal Statistical Office, Quality Report, "Kostenstrukturerhebung im Verarbeitenden Gewerbe, im Bergbau sowie in der Gewinnung von Steinen und Erden," *Kostenstrukturerhebung* (Wiesbaden: 2015).

Figure 1

R&D expenditures and R&D personnel in manufacturing industry

2010 = 100



Source: Federal Statistical Office, calculations by DIW Berlin.

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There has been a strong increase in R&D expenditures since the 2008/09 recession.

nomics crisis, R&D spending only increased slightly (by two percent from 2007 to 2008) and then declined markedly (by 7.3 percent from 2008 to 2009). From 2010 to 2013, however, R&D investment rose considerably and in 2013, it was almost 22 percent above the 2010 level (see Figure 1).

With an annual average of 6.8 percent, R&D grew more strongly from 2010 to 2013 than before the crisis (4.3 percent, see Table 1). Considering the period from 2008 to 2013 annual increase on average was lower (3.2 percent).

The research-intensive sectors increased their R&D investment from 2010 to 2013 by as much as 7.2 percent as an annual average. The increase was therefore almost twice as high as in the years before the crisis (3.7 percent). In vehicle construction (motor vehicle industry and other transport equipment), the difference was even greater. R&D spending after the crisis increased by 10.8 percent, but by only 3.6 percent in the years before the crisis.⁸

A different picture emerges in the chemical and pharmaceutical industry. Here, R&D spending hardly increased at all after the crisis (by only 0.2 percent). Before the crisis, there was an increase of almost three percent. Even during the crisis years, this sector expanded its R&D investment further (by 2.5 percent). The pharmaceutical industry is primarily responsible for this development. It slowed its R&D spending between 2010 and 2013 by

⁸ In motor vehicle construction, the ratio was 3 percent (2004 to 2008) to 11.7 percent (2010 to 2013). As annual rates of change at the current end show, R&D expenditure increased steadily from 2010 to 2013.

Table 1

R&D expenditures in manufacturing industry

Annual average rate of change and annual rate of change in percent

	2008 compared to 2004	2010 compared to 2008	2013 compared to 2010	2013 compared to 2008	2011 compared to 2010	2012 compared to 2011	2013 compared to 2012
Manufacturing total ¹	4.3	-2.1	6.8	3.2	9.2	6.9	4.4
R&D-intensive branches	3.7	-2.4	7.2	3.3	10.0	7.7	4.2
Chemical and pharmaceutical products ²	2.7	2.5	0.2	1.1	3.2	3.6	-5.8
Pharmaceutical products ³	.	-0.8	-5.0	-3.3	-2.0	4.8	-16.4
Mechanical engineering ⁴	14.4	-0.5	6.8	3.8	6.6	10.4	3.3
Manufacture of motor vehicles, trailers and semi-trailers and other transport equipment ⁵	3.6	-2.8	10.8	5.2	13.2	9.3	10.0
Data processing equipment, electronic, optical and electrical products ⁶	-1.3	-6.4	5.4	0.5	11.8	4.9	-0.1
Other branches	11.4	1.0	2.5	1.9	2.4	-1.1	6.2
Food industry ⁷	6.0	-8.3	8.3	1.4	10.6	6.5	7.9
Rubber and plastic products; Manufacture of metallic products ⁸	1.5	0.9	3.3	2.4	6.8	3.3	0.1
Manufacture of basic metals and of fabricated metal products ⁹	5.7	-3.7	4.1	0.9	0.9	7.1	4.5
Companies with ... employees							
20 to 49	1.2	1.0	3.6	2.6	2.3	-2.0	11.0
50 to 99	3.0	7.7	-2.0	1.8	0.9	-3.5	-3.2
100 to 249	7.7	0.9	-0.3	0.2	1.4	-4.9	2.8
250 to 499	1.7	3.9	10.5	7.8	7.6	17.0	7.2
500 to 999	7.1	-6.3	4.2	-0.1	14.6	0.2	-1.4
1,000 or more	4.1	-2.4	7.4	3.3	9.6	7.7	4.8

1 Until 2007: NACE Rev. 1.1 code, as of 2008: NACE Rev. 2 code.

2 NACE Rev. 1.1: 24, NACE Rev. 2: 20, 21.

3 NACE Rev. 2: 21.

4 NACE Rev. 1.1: 29, NACE Rev. 2: 28.

5 NACE Rev. 1.1: 34, 35, NACE Rev. 2: 29, 30.

6 NACE Rev. 1.1: 30 to 33, NACE Rev. 2: 26, 27.

7 NACE Rev. 1.1: 15, NACE Rev. 2: 10, 11.

8 NACE Rev. 1.1: 25, 26, NACE Rev. 2: 22, 23.

9 NACE Rev. 1.1: 27, 28, NACE Rev. 2: 24, 25.

Source: Federal Statistical Office, calculations by DIW Berlin.

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an annual average of five percent, while R&D investment in other chemical industries rose by 4.5 per cent. That the fall in R&D expenditure in the pharmaceutical industry was concentrated in 2013 with a decline of 16 percent indicates company-specific decisions such as the divestment or closure of R&D departments rather than a general trend in the industry.

In contrast to the research-intensive sectors, the less research-intensive industries increased their R&D investment considerably less after the crisis (2.5 percent) than before it (11.4 percent), although there are exceptions such as the food industry or the manufacture of rubber, plastic, and glass products.

Among small and medium-sized enterprises (SMEs, businesses with fewer than 250 employees⁹), too, spend-

ing on R&D after the crisis was weak which ran contrary to the trend in the industry overall—and also contrary to developments before and during the crisis. Among small businesses (50 employees or fewer), average annual growth was 3.6 per cent from 2010 to 2013 and R&D spending even fell among larger SMEs (50 to 249 employees). However, from 2004 to 2010, spending increased, particularly among larger SMEs. Major companies with more than 1,000 employees overcame the slump during the crisis relatively easily. R&D spending in these companies rose by an average of 7.4 per cent from 2010 to 2013, considerably more than before the crisis (4.1 percent). Among medium-sized companies (250 to 499 employees), a similar pattern emerged.

sheet total of up to 43 million euros. These companies must also be independent. The present report follows this definition and defines SMEs as companies with fewer than 250 employees. However, there is no information about the independence of the companies. The Institute for SME Research in Bonn defines an SME as an independent firm with fewer than 500 employees and a turnover of less than 50 million euros.

⁹ The European Commission defines SMEs as companies with fewer than 250 employees and with a turnover of up to 50 million euros or a balance

Measured by the amount of research spending, the most important sector by far is the vehicle industry: in 2013, this sector spent a total of 24.8 billion euros or 43.4 percent of total R&D spending in the manufacturing industry. The automotive industry alone invested 22.2 billion euros in research and development and together with three other research-intensive sector groups, the electrical engineering industry,¹⁰ mechanical engineering, and the chemical industry,¹¹ accounted for 91.6 percent of all industrial spending on research (see Table 2). The above-average growth in these sectors after the crisis meant that the share of industrial research and development increased slightly. In 2010, the major companies accounted for just under 80 percent of R&D spending. In 2013, it was 1.3 percentage points more. While the share of medium-sized companies (250 to 499 employees) remained virtually unchanged at almost 13 percent, SMEs accounted for only 6.1 percent of industrial R&D in 2013, although before the crisis in 2010 they had increased their share up to 7.5 percent.

R&D employment developed less volatile than R&D spending. During the crisis years, employment increased moderately (0.8 percent). From 2010 to 2013, the figure then increased by an average of 3.2 percent to almost 341,200 R&D employees (see Table 3). Growth after the crisis was therefore greater than in the four years before the crisis (1.4 percent). There were also parallels between the growth pattern of R&D spending and the development of the sectors and size classes.

Impact of demand on R&D is marginal

In terms of which factors influenced development during and after the crisis, the initial assumption seems to be correct that companies reduce their R&D activities to save money if demand for their products falls—and vice versa.¹² However, counter-cyclical behavior might also be plausible: consequently, companies with more favorable sales were able to employ more personnel in production and, in phases of weak demand, more in the development of new products. It is also conceivable that companies did not allow sales fluctuations to affect their

¹⁰ Manufacture of computer, electronic, and optical products, and of electrical equipment.

¹¹ Including the pharmaceutical industry.

¹² See also M. Ouyang, "On the Cyclicity of R&D," *The Review of Economics and Statistics* 93, no. 2 (2011): 542-553.

Table 2

R&D expenditures in manufacturing industry
Structure in percent

	2004	2006	2008	2009	2010	2011	2012	2013
Manufacturing total ¹	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
R&D-intensive branches	93.1	93.5	91.0	90.6	90.4	91.0	91.7	91.6
Chemical and pharmaceutical products ²	14.9	14.4	14.0	15.1	15.4	14.5	14.1	12.7
Pharmaceutical products ³	.	.	7.1	6.8	7.3	6.5	6.4	5.1
Mechanical engineering ⁴	11.4	11.1	16.5	16.9	17.0	16.6	17.2	17.0
Manufacture of motor vehicles, trailers and semi-trailers and other transport equipment ⁵	40.6	41.4	39.5	38.7	38.9	40.3	41.2	43.4
Data processing equipment, electronic, optical and electrical products ⁶	26.2	26.7	21.0	19.9	19.1	19.6	19.2	18.4
Other branches	6.9	6.5	9.0	9.4	9.6	9.0	8.3	8.4
Food industry ⁷	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Rubber and plastic products; Manufacture of metallic products ⁸	2.5	2.2	2.3	2.4	2.4	2.4	2.3	2.2
Manufacture of basic metals and of fabricated metal products ⁹	2.5	2.4	2.6	2.4	2.5	2.3	2.3	2.3
Companies with ... employees								
20 to 49	0.8	0.8	0.7	0.8	0.8	0.7	0.7	0.7
50 to 99	1.6	1.4	1.5	1.6	1.8	1.7	1.5	1.4
100 to 249	4.1	4.1	4.7	4.8	5.0	4.6	4.1	4.0
250 to 499	5.6	5.4	5.1	5.4	5.7	5.6	6.1	6.3
500 to 999	6.8	7.2	7.5	7.2	6.9	7.2	6.8	6.4
1,000 or more	81.1	81.0	80.6	80.2	79.9	80.2	80.8	81.2
For information: Manufacturing in billion euros	41,266	45,802	48,900	45,311	46,912	51,248	54,768	57,161

1-9 Definition of sectors see table 1.

Source: Federal Statistical Office, calculations by DIW Berlin.

Table 3

R&D employees in manufacturing industry

Annual average rate of change and annual rate of change in percent

	2008 compared to 2004 ¹	2010 compared to 2008	2013 compared to 2010	2011 compared to 2010	2012 compared to 2011	2013 compared to 2012
Manufacturing total ¹	1.4	0.8	3.2	5.7	1.2	2.6
R&D-intensive branches	0.5	0.5	3.4	6.0	1.6	2.6
Chemical and pharmaceutical products ²	-0.3	1.1	1.3	1.8	-4.3	6.6
Pharmaceutical products ³	.	-5.6	0.0	-1.6	-8.7	11.3
Mechanical engineering ⁴	6.8	1.9	4.2	4.3	4.3	4.0
Manufacture of motor vehicles, trailers and semi-trailers and other transport equipment ⁵	-0.1	1.2	3.6	8.8	2.0	0.2
Data processing equipment, electronic, optical and electrical products ⁶	-2.3	-1.7	3.5	6.0	1.8	2.8
Other branches	7.8	2.8	1.8	4.0	-1.0	2.4
Food industry ⁷	5.9	-0.5	0.1	0.4	1.5	-1.5
Rubber and plastic products; Manufacture of metallic products ⁸	0.2	0.6	4.0	6.2	0.0	5.8
Manufacture of basic metals and of fabricated metal products ⁹	5.5	-1.3	1.3	4.1	1.8	-1.9
Companies with ... employees						
20 to 49	2.1	2.3	0.8	-3.8	1.4	5.1
50 to 99	2.3	4.5	-0.9	-0.8	-7.7	6.2
100 to 249	5.2	2.5	-2.0	5.1	-13.1	3.0
250 to 499	0.3	3.4	8.1	6.0	13.3	5.4
500 to 999	2.9	-3.6	3.7	9.1	1.8	0.5
1,000 or more	0.8	0.7	3.3	6.0	1.9	2.2

1-9 Definition of sectors see table 1.

Source: Federal Statistical Office, calculations by DIW Berlin.

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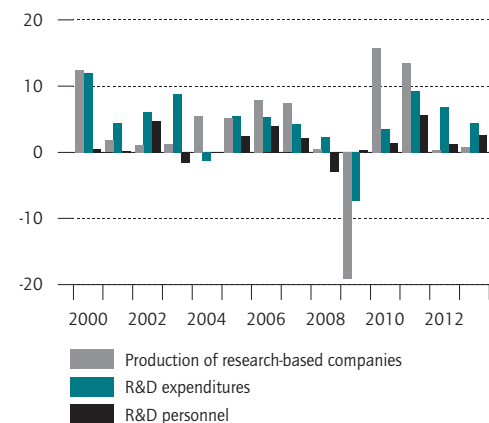
strategic plans and viewed R&D as a long-term investment.¹³ Companies might also have responded to demand fluctuations by outsourcing R&D activities or re-integrating them again (insourcing).

A comparison of the development of production and R&D does not reveal a uniform picture: in some years, the rates of change in R&D spending were greater than the production of research-based companies; in other years, however, they were lower (see Figure 2). Even after the crisis, there was no clear correlation: in 2011, the increase in production exceeded growth in R&D spending, while in 2012 and 2013, R&D spending rose faster than production. This indicates that the impact of the business cycle on R&D is not very pronounced. This applies to most of the sectors included in the present report (see Table 4). Thus, the growth rates of R&D spending in research-intensive industries during and particularly after the crisis were greater than those of production. In the less research-intensive industries, R&D spending expanded during the crisis, despite declining produc-

Figure 2

R&D expenditures, R&D personnel, and production of research-based companies in manufacturing industry

Change in comparison with previous year in percent



Source: Federal Statistical Office, calculations by DIW Berlin.

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The development of R&D employment is less volatile than R&D expenditures.

13 See also P. Arqué-Castells, "Persistence of R&D Performance and its Impact for the Granting of Subsidies," *Review of Industrial Organization* 43, no. 3 (2013): 193-220.

Table 4

Production and R&D expenditures in research-based companies in manufacturing industry

Annual average rate of change in percent

	Production	Production less R&D expenditures	Production	Production less R&D expenditures	Production	Production less R&D expenditures
	2008 compared to 2004		2010 compared to 2008		2013 compared to 2010	
	Manufacturing total ¹	5.2	-0.9	-3.3	1.2	4.7	2.1
R&D-intensive branches	4.4	-0.6	-3.0	0.6	4.7	2.6
Chemical and pharmaceutical products ²	5.6	-2.9	3.1	-0.6	3.2	-3.0
Pharmaceutical products ³	.	.	-6.7	5.9	6.4	-11.4
Mechanical engineering ⁴	9.8	4.6	-6.6	6.1	5.5	1.3
Manufacture of motor vehicles, trailers and semi-trailers and other transport equipment ⁵	3.3	0.4	-2.3	-0.5	6.5	4.3
Data processing equipment, electronic, optical and electrical products ⁶	0.4	-1.7	-5.8	-0.7	1.0	4.4
Other branches	7.4	4.0	-4.0	5.0	4.9	-2.4
Food industry ⁷	4.0	2.0	-1.7	-6.6	8.1	0.2
Rubber and plastic products; Manufacture of metallic products ⁸	3.1	-1.5	-1.7	2.6	5.7	-2.4
Manufacture of basic metals and of fabricated metal products ⁹	10.2	-4.5	-7.8	4.1	3.4	0.7
Companies with ... employees						
20 to 49	4.7	-3.5	-2.8	3.8	3.0	0.6
50 to 99	5.4	-2.4	1.6	6.1	1.0	-3.0
100 to 249	6.8	0.9	-1.8	2.7	1.9	-2.2
250 to 499	6.8	-5.1	-0.7	4.6	4.7	5.8
500 to 999	7.9	-0.9	-5.7	-0.5	3.8	0.4
1,000 or more	4.4	-0.2	-3.6	1.2	5.4	2.0

1-9 Definition of sectors see table 1.

Source: Federal Statistical Office, calculations by DIW Berlin.

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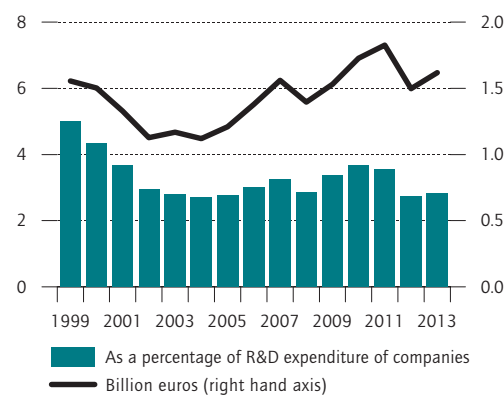
tion—after the crisis, however, the reverse was true. Major companies exhibit a similar pattern to that observed in the research-intensive industries. SMEs expanded their spending on research and development during the crisis, despite declining demand.

Fall in funding intensity after crisis

Companies' R&D spending could also have affected the scale of government funding: the volume of grants from the German central government¹⁴ rose sharply between 2008 and 2011 from 1.4 to 1.8 billion euros (see Figure 3) and, as a result, funding intensity climbed from 2.9 to 3.6 percent of R&D spending. As part of the second economic stimulus package, the volume of subsidies from the Central Innovation Program for SMEs (*Zentrales Innovationsprogramm Mittelstand, ZIM*) increased dra-

Figure 3

Federal government funding for R&D in manufacturing companies



Sources: Federal Statistical Office; Federal Ministry of Education and Research, calculations by DIW Berlin.

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Funding for R&D by the federal government was raised significantly until 2011 and reduced thereafter.

¹⁴ In the absence of other information, only funding from central government is taken into account. See Federal Ministry of Education and Research (BMBF) (pub.), *Federal Report on Research and Innovation 2014* (Berlin: 2014) and <http://www.datenportal.bmbf.de/portal/de/index.html>.

Table 5

Number of research-based companies in manufacturing industry

	2004	2006	2008	2009	2010	2011	2012	2013
Manufacturing total ¹	8,773	8,827	9,509	9,421	9,493	9,547	9,434	9,664
R&D-intensive branches	5,454	5,517	5,434	5,323	5,390	5,458	5,214	5,425
Chemical and pharmaceutical products ²	784	801	777	771	778	795	745	805
Pharmaceutical products ³	.	.	106	99	103	105	105	120
Mechanical engineering ⁴	2,171	2,207	2,316	2,253	2,290	2,311	2,145	2,224
Manufacture of motor vehicles, trailers and semi-trailers and other transport equipment ⁵	423	434	492	479	476	469	452	454
Data processing equipment, electronic, optical and electrical products ⁶	2,076	2,075	1,849	1,820	1,847	1,883	1,872	1,943
Other branches	3,319	3,311	4,075	4,098	4,103	4,090	4,219	4,239
Food industry ⁷	327	362	446	441	436	424	439	421
Rubber and plastic products; Manufacture of metallic products ⁸	1,032	985	1,037	1,067	1,065	1,044	1,114	1,116
Manufacture of basic metals and of fabricated metal products ⁹	1,061	1,083	1,255	1,254	1,249	1,266	1,309	1,331
Companies with ... employees								
20 to 49	1,886	1,860	2,015	2,047	2,056	1,985	2,019	2,094
50 to 99	2,013	2,030	2,227	2,214	2,259	2,235	2,084	2,210
100 to 249	2,401	2,503	2,710	2,689	2,720	2,777	2,683	2,700
250 to 499	1,282	1,279	1,323	1,301	1,309	1,356	1,447	1,453
500 to 999	660	640	704	662	657	694	695	695
1,000 or more	531	516	531	509	492	500	506	511

1–9 Definition of sectors see table 1.

Source: Federal Statistical Office, calculations by DIW Berlin.

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matically.¹⁵ This took the government cofinancing rate for SMEs to an estimated ten percent¹⁶ and is likely to have helped ensure that R&D spending among SMEs did not decline during the crisis. The funding intensity diminished greatly once the special subsidies expired, particularly among small and medium-sized enterprises. This could have led to a decline in R&D spending by these companies since 2010.

Slight increase in number of research-based companies since 2009

Another possible explanation for the increased R&D spending after 2009 could be that the number of research-based companies rose more sharply than before the crisis. However, this was not the case: in 2013, there were 9,664 research and development companies (see

Table 5). This was 171 more than in 2010, representing an average annual increase of 0.6 percent. However, in the years before the crisis, the average annual increase in research companies was two percent.¹⁷

In some research-intensive sectors, such as mechanical engineering and vehicle construction, the number of research-based companies has declined (see Table 6). There were also fewer research companies classified as SMEs with 50 to 249 employees. In contrast, the number of research enterprises among the major companies increased. However, this development could also have been the result of companies moving up a size class due to employment growth in the subsequent year. Overall, the changes in the number of research companies provide no explanation for the strong growth in R&D spending after the crisis.

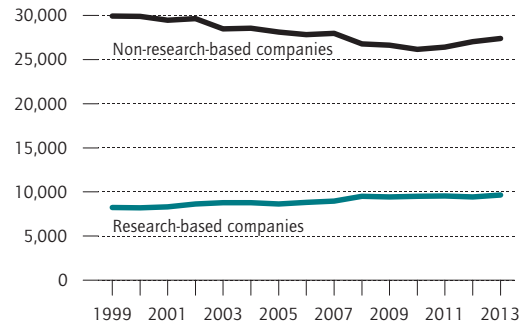
¹⁵ The additional funds amounted to 53 million euros in 2009, to 320 million euros in 2010, and to 397 million euros in 2011. See BMBF (pub.), *Federal Report on Research and Innovation 2014* (Berlin: 2014), 444.

¹⁶ A. Eickelpasch, "Research-Based Companies Perform Better," *DIW Economic Bulletin* 10 (2012).

¹⁷ It should be noted that companies that start research work or take it up again from one year to the next (or temporarily or permanently discontinue it) spend very little on R&D and their contribution to total R&D spending is negligible. A. Eickelpasch, "R&D Behavior of German Manufacturing Companies during the 2008/09 Recession," *DIW Discussion Papers* 1357 (Berlin: 2014).

Figure 4

Number of research-based and non-research-based companies in manufacturing industry



Source: Federal Statistical Office, calculations by DIW Berlin.

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Only slight increase of the number of research-based companies after 2009.

It is interesting to note that the number of non-research-based companies has also increased recently, rising by approximately 27,400 or 4.5 percent from 2010 to 2013 (see Figure 4). The growth in this sector was therefore higher than among research-based companies, which is why the share of all businesses accounted for by research-based companies decreased slightly (26.6 percent in 2010 and 26.1 percent in 2013). This share has declined in most sectors (see Table 7). Analyzing the data according to company size shows that for SMEs, the share of research-based companies declined slightly from 2010 to 2013. In contrast, for companies with 250 to 1,000 employees, it increased considerably. Overall, the time comparison indicates that the percentages did not change significantly in the years after the crisis.

R&D intensity has further increased

To calculate the intensity of R&D spending, R&D investment by research-based companies is set against gross value added. This shows how much of its generated performance a company has invested in research and development. In 2013, R&D spending amounted to 18.3 percent of the added value of research-based companies, while three years earlier it was 16.4 percent. For comparison: in 2010, R&D spending as a proportion of the total added value of the industry reached 11.3 percent and in 2013, the corresponding figure was 12.7 percent (see Figure 5).

In 2013, R&D intensity of research-based companies in research-intensive sectors was 22.6 percent and 5.9 percent in the less research-intensive sectors. Vehicle con-

Table 6

Research-based companies in manufacturing industry

Annual average rate of change in percent

	2008 compared to 2004	2010 compared to 2008	2013 compared to 2010
Manufacturing total ¹	2.0	-0.1	0.6
R&D-intensive branches	-0.1	-0.4	0.2
Chemical and pharmaceutical products ²	-0.2	0.0	1.1
Pharmaceutical products ³	.	-1.6	5.4
Mechanical engineering ⁴	1.6	-0.6	-1.0
Manufacture of motor vehicles, trailers and semi-trailers and other transport equipment ⁵	3.9	-1.7	-1.5
Data processing equipment, electronic, optical and electrical products ⁶	-2.8	-0.1	1.7
Other branches	5.3	0.3	1.1
Food industry ⁷	8.0	-1.1	-1.2
Rubber and plastic products; Manufacture of metallic products ⁸	0.1	1.4	1.6
Manufacture of basic metals and of fabricated metal products ⁹	4.3	-0.3	2.2
Companies with ... employees			
20 to 49	1.7	1.0	0.6
50 to 99	2.6	0.7	-0.7
100 to 249	3.1	0.2	-0.3
250 to 499	0.8	-0.5	3.5
500 to 999	1.6	-3.4	1.9
1,000 or more	-0.0	-3.7	1.3

1-9 Definition of sectors see table 1.

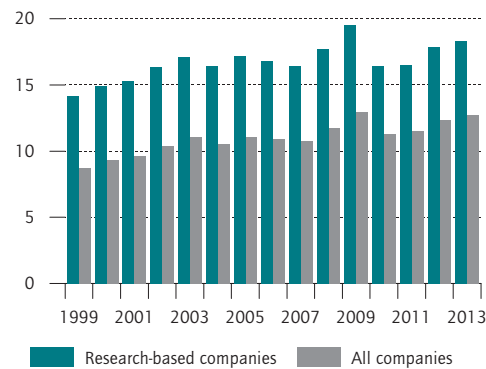
Source: Federal Statistical Office, calculations by DIW Berlin.

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Figure 5

R&D intensity in manufacturing industry

R&D expenditures as percent of value added



Source: Federal Statistical Office, calculations by DIW Berlin.

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R&D intensity has increased since 2010 again.

Table 7

Research-based enterprises as percentage of all companies
In percent

	2004	2006	2008	2009	2010	2011	2012	2013
Manufacturing total ¹	23.5	24.1	26.2	26.1	26.6	26.6	25.9	26.1
R&D-intensive branches	40.8	41.5	47.0	47.3	48.4	48.5	45.6	46.3
Chemical and pharmaceutical products ²	56.6	57.0	55.5	55.1	55.9	56.0	51.8	53.9
Pharmaceutical products ³	.	.	43.9	41.5	42.8	42.5	42.0	45.1
Mechanical engineering ⁴	36.3	37.1	42.7	43.6	45.0	45.0	41.0	41.6
Manufacture of motor vehicles, trailers and semi-trailers and other transport equipment ⁵	32.4	33.3	38.6	37.7	37.4	37.1	35.8	35.3
Data processing equipment, electronic, optical and electrical products ⁶	44.1	44.7	53.4	53.3	54.8	54.9	53.6	54.0
Other branches	13.8	14.2	16.5	16.5	16.7	16.6	16.9	16.7
Food industry ⁷	6.6	7.3	8.7	8.6	8.5	8.2	8.5	8.1
Rubber and plastic products; Manufacture of metallic products ⁸	24.1	23.7	24.7	25.7	26.0	25.1	26.4	26.1
Manufacture of basic metals and of fabricated metal products ⁹	15.0	15.4	17.1	16.8	16.9	17.0	17.2	17.1
Companies with ... employees								
20 to 49	11.1	11.6	13.1	12.7	13.2	12.9	12.7	12.7
50 to 99	21.2	21.1	23.3	24.1	24.3	23.9	22.5	23.8
100 to 249	35.2	36.0	37.9	39.5	39.8	39.2	37.4	37.8
250 to 499	53.7	53.2	53.9	55.7	55.7	55.7	58.9	58.6
500 to 999	63.1	62.6	67.2	67.5	67.3	67.0	66.3	65.8
1,000 or more	77.9	78.0	79.2	79.5	78.3	78.1	77.2	77.5

1-9 Definition of sectors see table 1.

Source: Federal Statistical Office, calculations by DIW Berlin.

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struction was top of the table at 30.9 percent (see Table 8). While R&D intensity in the research-intensive sectors has increased markedly (by 2.6 percentage points from 2010 to 2013), it has remained roughly the same in the less research-intensive sectors (-0.1 percentage points).

Among small and medium-sized enterprises, R&D intensity is considerably lower than the industry average of around eight percent. It is a little higher among the "small" major companies (250 to 999 employees) at almost ten percent, while the intensity among the major enterprises is two or even three times higher (23.9 percent). For small businesses with fewer than 50 employees, the figure increased considerably between 2010 to 2013 (by 0.7 percentage points) and decreased among medium-sized companies. Since R&D intensity has risen in the "small" major companies (by 0.4 percent) and growth in the larger companies with more than 1,000 employees was even more significant (by 2.7 percentage points), the gap between them and SMEs has widened further.

Also in terms of personnel, R&D intensity among research-based companies rose after the crisis, albeit only

slightly: in 2010, the share of R&D employees of all employees in research companies was 9.1 percent¹⁸ and in 2013, the corresponding figure was 9.4 percent (see Table 9), thus surpassing pre-crisis levels only slightly.

In the research-intensive industry sectors, R&D personnel intensity was considerably higher than in other industry sectors — as was R&D spending intensity. However, the differences were not as pronounced.¹⁹ Among the major research-based companies with 1,000 or more employees, a larger share was involved in research and development (11.8 percent in 2013) than the industry average. Among small businesses (20 to 49 employees), the share was — as in previous years — also above average (10.5 percent). One explanation could be that R&D personnel in this company group only work occasionally in research and development and not exclusively.

¹⁸ In addition, the number of R&D employees can also be referenced in relation to the number of employees in the entire manufacturing sector. In 2010, the share of researchers among *all* employees in manufacturing was 5.4 percent and in 2013 the corresponding figure was 5.5 percent.

¹⁹ The reason why this sector has a higher "R&D spending intensity" than "R&D personnel intensity" may be because R&D investments (as a component of R&D spending) are particularly high here.

Table 8

R&D expenditures in percent of total value added of research-based companies

In percent

	2004	2006	2008	2009	2010	2011	2012	2013	2008 less 2004	2010 less 2008	2013 less 2010
Manufacturing total ¹	16.4	16.8	17.7	19.5	16.4	16.5	17.8	18.3	1.3	-1.3	1.9
R&D-intensive branches	20.4	20.6	22.0	24.8	20.0	20.2	22.2	22.6	1.5	-2.0	2.6
Chemical and pharmaceutical products ²	18.1	17.5	17.3	18.9	17.0	17.3	19.0	17.6	-0.8	-0.3	0.7
Pharmaceutical products ³	.	.	29.1	29.3	29.4	26.1	27.0	22.2	.	0.3	-7.3
Mechanical engineering ⁴	10.5	10.4	14.0	16.9	14.9	14.4	16.0	16.1	3.4	0.9	1.2
Manufacture of motor vehicles, trailers and semi-trailers and other transport equipment ⁵	27.1	27.1	32.8	39.6	26.9	26.5	28.8	30.9	5.6	-5.9	4.1
Data processing equipment, electronic, optical and electrical products ⁶	22.7	23.9	22.2	22.7	18.7	19.9	21.8	21.4	-0.5	-3.5	2.7
Other branches	4.5	4.5	5.9	6.4	6.1	5.8	5.6	5.9	1.5	0.1	-0.1
Food industry ⁷	2.8	3.1	3.3	2.7	2.8	2.9	2.9	3.2	0.6	-0.6	0.4
Rubber and plastic products; Manufacture of metallic products ⁸	6.0	5.9	6.2	7.0	6.5	6.4	6.4	6.3	0.2	0.3	-0.2
Manufacture of basic metals and of fabricated metal products ⁹	4.2	4.3	4.4	5.1	4.8	4.3	4.6	4.9	0.2	0.4	0.1
Companies with ... employees											
20 to 49	9.6	9.4	8.8	10.1	8.9	8.6	8.8	9.6	-0.8	0.1	0.7
50 to 99	7.8	7.3	7.9	8.9	8.5	7.9	8.6	8.0	0.0	0.7	-0.6
100 to 249	7.3	7.5	8.1	8.9	8.4	8.1	8.1	8.2	0.9	0.3	-0.3
250 to 499	8.1	7.8	7.5	8.7	8.2	8.3	9.3	9.6	-0.6	0.7	1.4
500 to 999	9.2	10.5	9.7	10.5	9.1	9.4	9.6	9.5	0.6	-0.6	0.4
1,000 or more	21.2	21.7	24.0	26.5	21.2	21.4	23.2	23.9	2.7	-2.7	2.7

1-9 Definition of sectors see table 1.

Source: Federal Statistical Office, calculations by DIW Berlin.

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Table 9

R&D personnel as percentage of total employees in research-based companies

In percent

	2004	2006	2008	2009	2010	2011	2012	2013	2008 less 2004	2010 less 2008	2013 less 2010
Manufacturing total ¹	8.3	9.0	8.6	8.9	9.1	9.3	9.3	9.4	0.3	0.5	0.3
R&D-intensive branches	10.2	11.1	10.7	11.1	11.3	11.6	11.6	11.8	0.5	0.6	0.4
Chemical and pharmaceutical products ²	11.1	11.4	11.5	11.8	12.0	11.8	11.4	11.8	0.4	0.5	-0.3
Pharmaceutical products ³	.	.	17.1	17.8	18.1	17.5	15.0	16.0	.	1.0	-2.1
Mechanical engineering ⁴	6.7	7.0	7.8	8.1	8.5	8.7	9.0	9.2	1.1	0.7	0.7
Manufacture of motor vehicles, trailers and semi-trailers and other transport equipment ⁵	10.7	11.9	12.0	12.6	12.9	13.4	13.3	13.1	1.3	0.9	0.2
Data processing equipment, electronic, optical and electrical products ⁶	12.6	13.9	12.1	12.7	12.4	12.7	12.8	13.1	-0.5	0.3	0.7
Other branches	3.2	3.4	3.8	4.0	4.2	4.2	4.1	4.1	0.6	0.4	-0.1
Food industry ⁷	2.3	2.6	2.7	2.5	2.8	2.7	2.6	2.7	0.4	0.0	-0.1
Rubber and plastic products; Manufacture of metallic products ⁸	3.9	4.1	4.1	4.3	4.4	4.4	4.2	4.5	0.2	0.3	0.1
Manufacture of basic metals and of fabricated metal products ⁹	2.8	3.1	3.3	3.2	3.4	3.4	3.4	3.3	0.5	0.1	-0.1
Companies with ... employees											
20 to 49	10.0	9.3	9.9	10.1	10.1	10.0	10.1	10.5	-0.1	0.2	0.3
50 to 99	6.9	6.4	6.9	7.2	7.4	7.4	7.2	7.3	-0.0	0.5	-0.1
100 to 249	5.4	5.6	5.8	6.1	6.1	6.3	5.7	5.8	0.4	0.3	-0.3
250 to 499	5.4	5.4	5.3	5.5	5.7	5.8	6.2	6.5	-0.1	0.4	0.8
500 to 999	5.9	6.7	6.2	6.2	6.2	6.4	6.5	6.5	0.3	-0.0	0.3
1,000 or more	10.0	11.2	10.7	11.2	11.6	11.7	11.7	11.8	0.7	0.9	0.2

1-9 Definition of sectors see table 1.

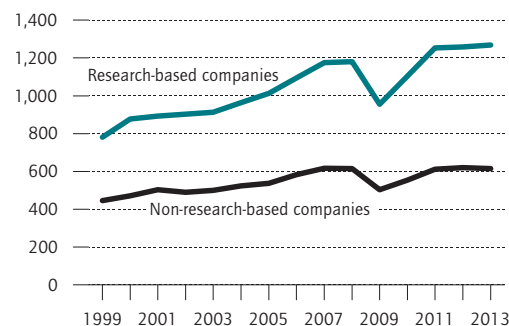
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Figure 6

Output in research-based and non-research-based companies in manufacturing industry

In billion euros



Source: Federal Statistical Office, calculations by DIW Berlin.

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The level of output of research-based companies relies heavily on exports.

Production and employment growth among research companies also increased after the crisis

In 2013, research-based companies generated a total of 67.4 percent of industrial production (gross value of production) or 1.27 trillion euros. Both before and after the crisis, they produced considerably more than non-research-based companies — although they experienced a more severe temporary slump in production caused by the crisis (see Figure 6). This was primarily because research companies are particularly export-oriented and were therefore hit harder by the global economic crisis. In 2013, the share of production by research-based companies of total production in the research-intensive sectors was around 85 percent and, in other industry sectors, almost 45 percent (see Table 10). If we look at the figures in terms of company size, a clear picture emerges: among small companies, the share of production accounted for by research-based companies is smaller than among medium-sized enterprises and, in turn, their share is smaller than the major companies.

Table 10

Production in research-based companies as percentage of total production

	2010	2011	2012	2013	2008 less 2004	2010 less 2008	2013 less 2010
Manufacturing total ¹	66.6	67.2	67.0	67.4	1.0	0.8	0.8
R&D-intensive branches	85.6	85.8	85.2	85.4	0.1	1.0	-0.2
Chemical and pharmaceutical products ²	81.4	81.2	79.4	80.3	-0.4	1.7	-1.1
Pharmaceutical products ³	76.4	75.7	76.9	77.9	.	-4.7	1.5
Mechanical engineering ⁴	81.8	81.0	80.7	81.2	3.1	2.2	-0.6
Manufacture of motor vehicles, trailers and semi-trailers and other transport equipment ⁵	90.3	91.2	90.9	91.0	-1.1	0.5	0.7
Data processing equipment, electronic, optical and electrical products ⁶	85.1	84.8	84.3	83.8	1.4	-0.5	-1.3
Other branches	43.2	44.3	44.6	44.6	3.1	0.3	1.4
Food industry ⁷	28.2	30.5	30.3	30.5	-0.7	0.5	2.2
Rubber and plastic products; Manufacture of metallic products ⁸	53.5	53.5	56.2	55.6	-2.6	0.7	2.1
Manufacture of basic metals and of fabricated metal products ⁹	54.4	54.6	55.8	54.6	1.2	0.6	0.2
Companies with ... employees							
20 to 49	16.5	16.8	15.9	15.5	1.5	0.1	-1.0
50 to 99	28.0	28.3	26.4	27.2	0.9	2.3	-0.8
100 to 249	42.9	41.9	40.0	41.2	3.1	2.6	-1.7
250 to 499	53.8	53.2	56.4	54.1	-2.6	3.6	0.3
500 to 999	61.8	63.0	60.7	63.1	7.0	-2.2	1.3
1,000 or more	85.8	86.4	86.1	86.7	0.1	0.3	0.9

1–9 Definition of sectors see table 1.

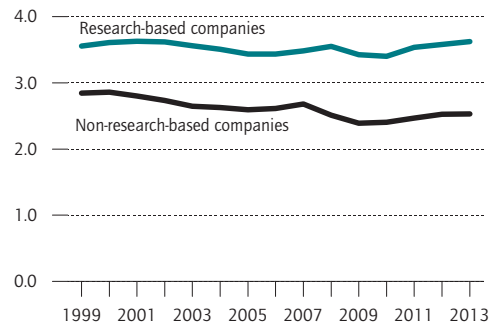
Source: Federal Statistical Office, calculations by DIW Berlin.

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Figure 7

Employees in research-based and non-research-based companies in manufacturing industry

In million persons



Source: Federal Statistical Office, calculations by DIW Berlin.

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The contribution of research-based companies to employment in manufacturing industry is steadily increasing.

In 2013, a total of 6.1 million people were employed in the industry as a whole and 3.6 million were employed at research-based companies — this figure was similarly high in 2010 (see Figure 7). In non-research sectors, the share of employment in research-based companies rose (by 0.7 percentage points to 36.9 percent) while in research-intensive industries this figure fell (by 0.5 percentage points to 80 percent). The share also decreased

among SMEs, but increased among companies with between 250 and 500 employees, and major companies. During the crisis, the research-based SMEs were still able to increase their share.

R&D development more dynamic in germany than other european countries

The leading countries in terms of overall economic R&D intensity were used as reference for an international comparison of R&D development in the manufacturing sector. The comparison shows a considerably more favorable development of R&D spending in German manufacturing than in other European countries (see Table 11). Finland was not able to maintain its pre-crisis level, R&D spending in Sweden rose only moderately, and in Austria it actually stagnated. In contrast, an upward trend was seen in France and the UK, although they still lagged behind development in Germany. Development in Israel, the US, and Japan was less favorable than in the German manufacturing industry. However, development in South Korea and in China was considerably more dynamic than in Germany. All in all, it appears that Germany is emerging more successfully out of the crisis than other European countries.

Conclusion

Germany’s industrial companies significantly curtailed their spending on research and development during the global economic and financial crisis of 2008 and 2009

Table 11

R&D expenditures¹ in manufacturing industry in selected countries

2010 = 100

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Germany	88	93	98	102	104	97	100	109	117	122
Finland	75	80	84	93	105	100	100	100	88	.
Sweden	.	.	.	95	111	104	100	102	102	106
Austria	70	83	87	93	99	95	100	100	.	.
France	.	.	.	105	108	102	100	104	109	.
UK	.	.	.	111	104	101	100	108	115	.
US	75	80	87	95	104	99	100	102	.	.
Israel	79	86	94	107	99	91	100	110	110	.
Korea	52	57	66	74	80	85	100	116	132	144
Japan	99	108	112	116	114	100	100	103	102	108
China	.	.	.	.	66	80	100	128	154	179
Taiwan	60	67	73	82	88	91	100	107	113	121

¹ R&D-Expenditure main activity, current prices, national currency.

Source: Germany: Federal Statistical Office (KSE), other countries: OECD STAN Database for Structural Analysis (ISIC Rev. 4), calculations by DIW Berlin.

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but increased it again considerably thereafter. Growth rates were higher from 2010 to 2013 than in the pre-crisis period from 2004 to 2008. The annual increase rate was smaller when considering a process of catching-up after crisis: From 2008 to 2013 companies raised research expenditures by annually 3.2 percent on average.

This trend is not uniform across all areas of the industry. The research-intensive industries and the larger companies, in particular, have increased R&D spending recently. In contrast, the trend among small and medium-sized enterprises was more positive before and during the crisis—firms with 50 to 249 employees actually reduced their R&D spending. The weighting has thus shifted in favor of research-intensive industries and the major companies. However, it should be noted that not every company has to do research in order to succeed.

The present study also examines which factors account for the increase in R&D spending after the crisis. The findings show that the R&D activities of companies do not depend solely on how demand for their products changes. In some years, production increased more than R&D spending, in other years, it was the reverse. This suggests that companies base their R&D decisions on other factors. Funding intensity rose sharply during the crisis and declined, particularly among small and medium-sized enterprises, when special government fund-

ing for SMEs ended. The number of research-based companies rose after the crisis but the new firms invested comparatively little in research and development. R&D spending growth is therefore mainly due to expansion among existing research companies.

R&D spending increased considerably faster after the crisis than the added value of the research-based companies. As a result, there has been another marked increase in the R&D intensity of the research-based companies since 2010. The major companies are still ahead on spending and the gap with SMEs has increased.

The share of production by research-based companies of total industrial production and the share of industrial employment even increased again after 2010, reaching a peak in 2013—the major companies played a leading role here, too.

In an international comparison, industrial R&D in Germany has developed more dynamically post-crisis than in other European countries. However, the increase remained below that of China and South Korea.

Overall, industrial research in Germany is on the right path. However, it should be noted that development is based upon larger companies, in particular, and also upon the already research-intensive industries.

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