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Financial Literacy and Financial Behavior

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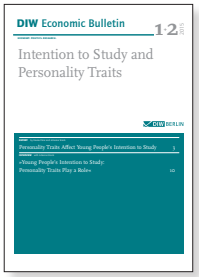

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NEXT WEEK IN DIW ECONOMIC BULLETIN

Job satisfaction in Germany

School, parents, and financial literacy shape future financial behavior

By Antonia Grohmann and Lukas Menkhoff

Why do some people make better financial decisions than others do? The level of financial literacy plays an important role: Quality schooling that also deals with financial issues likewise leads to better financial decisions. However, many studies neglect how parenting also influences financial behavior. This report shows that parents also have an indirect effect on the financial literacy of their adult children; in general, specific financial training actually has less of an effect on financial behavior.

Competency in financial matters is extremely useful. This applies not only to businesses but increasingly to individuals, as well. Households have more financial assets than they used to. Many people have to service loans. More and more often, they have to use savings for their retirement and, when it comes to buying insurance, they are faced with a wide variety of products to choose from. Ideally, good financial decisions increase wealth, prevent over-indebtedness, finance retirement, and insure against major life contingencies.

Studies show, however, that many individuals make poor choices: some households invest all of their assets in a house (that they live in), hold stock primarily in the company where they work, or possess only savings deposits (with low interest). Others take out overpriced loans or are heavily indebted.

Interestingly, the quality of these financial decisions is closely related to the decision-maker's level of financial literacy, as shown by many studies.[1] This seems obvious, considering that relevant knowledge should lead to better decisions.[2] However, these studies also show that financial literacy levels are often very low.

The logic response from economic policy-makers has been to promote financial literacy. The OECD, for instance, published financial education guidelines in 2005.[3] In Germany, all *Länder* have now integrated elements of financial education in their school curricula, albeit with great variation in the type and intensity of the programs.[4] Although targeted educational programs ap-

1 Annamaria Lusardi and Olivia S. Mitchell, "The Economic Importance of Financial Literacy: Theory and Evidence," *Journal of Economic Literature* 52 (2014): 5–44.

2 Tabea Bucher-Koenen and Annamaria Lusardi, "Financial Literacy and Retirement Planning in Germany," *Journal of Pension Economics and Finance* 10 (4) (2011): 565–584.

3 OECD, "Recommendation on Principals and Good Practices for Financial Education and Awareness," July 2005.

4 Hans Kaminski and Stephan Friebel, "Finanzielle Allgemeinbildung als Bestandteil ökonomischer Bildung" (2012), accessed June 22, 2015, www.ioeb.de/sites/default/files/img/Aktuelles/120814_Arbeitspapier_Finanzielle_Allgemeinbildung_Downloadversion.pdf and Günther Seeber, "Ökonomische Bildung in der Schule, Notwendigkeit und Handlungsbedarfe" (2006), accessed June 23, 2015, https://www.uni-koblenz-landau.de/de/landau/fb6/sowi/iww/team/Professoren/seeber/WHL2006.

pear to be a fundamentally sensible approach, an evaluation of these programs has yielded disappointing results.[5] On average, the effect of improved knowledge on behavior was found to be limited and to diminish considerably over time.[6] There are numerous possible causes for this. The present article focuses primarily on the impact that family background and other childhood experiences may have on financial literacy and financial behavior.

The different channels of financial socialization

As mentioned above, targeted financial training has a surprisingly weak effect on financial behavior. One reason for this might be that financial socialization plays a key role in financial behavior. Financial socialization refers to the process by which individuals acquire not only theoretical knowledge of financial matters but also learn attitudes and behaviors that have an effect on their financial behavior.

Just as with other forms of socialization, financial socialization begins in childhood. For example, having children keep a bank account teaches them behaviors that may continue into adulthood. Financial socialization occurs through different channels; school, work, and family can all have an effect. Studies show that family has the strongest impact on financial socialization.[7]

How childhood experience shapes adult financial behavior

Economic studies on the impact of financial literacy on financial behavior tend not to address issues of family background such as parental teaching. There are three possible reasons for this. First, this information is usually not available . Second, financial training is seen as an exogenous effect (independent of family background). And third, the possibility of factoring in teaching and family is considered to be going too far, as the focus of these studies is on the effect of financial literacy on financial behavior.

While these limitations do generally apply, there are some studies that use information on the childhood experiences of their adult subjects.[8] This information is usually collected to facilitate the estimation of reliable coefficients, since while financial literacy presumably affects financial behavior, the reverse effect may also be true.[9] It is conceivable, for example, that people learn about finance when they use certain financial products.

The literature focuses primarily on five channels through which childhood experience may affect financial literacy: (1) parents' level of education, (2) parental teaching, (3) economics in school, (4) quality of education, and (5) learning through experiences with money in childhood. For example, one aspect of family background that is seen as relevant for financial literacy is

5 Melanie Lührmann, Maria Serra-Garcia, and Joachim Winter, "Teaching Teenagers in Finance: Does It Work?," *Journal of Banking and Finance* 54 (2015): 160–174.

6 Daniel Fernandes, John G. Lynch, and Richard G. Netemeyer, "Financial Literacy, Financial Education and Downstream Financial Behavior," *Management Science* 60 (2014): 1861–1883.

7 Soyen Shim, Bonnie L. Barber, and Noel A. Card, "Financial Socialization of First-year College Students: The Roles of Parents, Work, and Education," *Journal of Youth and Adolescence* 39 (2009/2010): 1457–1470.

8 Jere Behrman, Olivia S. Mitchell, Cindy Soo, and David Bravo, "Financial Literacy, Schooling, and Wealth Accumulation," *NBER Working Paper Series*, no. 16452.

9 A reverse effect can be ruled out, however, if the estimate uses what is called an instrument. These instruments are often variables that characterize childhood experience, since the instrument must be correlated with financial literacy but may not be correlated with financial behavior.

Box 1

Effect of childhood experiences on financial literacy – five factors

1. Parents' educational background

   What is the highest level of education completed by your mother?
   What is the highest level of education completed by your father?

2. Finance and parental teaching

   Did your parents encourage you to save money?
   Did your parents teach you how to budget?

3. Economics in school

   Did you take economics in school?

4. Quality of education

   Were you born in Bangkok?
   Did you complete your highest level of education in Bangkok?

5. Learning through experiences with money in childhood

   Did you have a job before the age of 15?
   Did you have a bank account before the age of 18?

the mother's education, specifically the highest level of education that she has completed (see Box 1).

How can financial literacy be measured?

Empirical studies of financial literacy require quantified measurements. It must be understood, however, that these measurements are only an approximation of actual literacy levels. Since collecting this kind of information is costly and respondents are often not eager to give long and complex answers, certain practical standards have been established. The simplest form of survey asks about three aspects of financial literacy, namely the respondent's understanding of interest, inflation, and diversification.

The present study is based on a survey conducted in Bangkok in December 2012. The questionnaire was developed, translated, and tested in cooperation with researchers from Mahidol University in Bangkok (see Box 2). The actual survey was conducted by a market research firm. It questioned 530 members of the middle class in Bangkok. More specifically, it included only individuals who earn a minimum income of approximately 400 euros per month and who are responsible or co-responsible for their own or their household's. Equal numbers of men and women aged 18 to 60 were surveyed. They were approached "on the street" in various neighborhoods in Bangkok.

Box 2

Questions regarding financial literacy

1. You borrow 10,000 Thai baht at an interest rate of two percent per month. How much do you owe after three months?

   a) Less than 10,200 Thai baht
   b) More than 10,200 Thai baht
   c) Exactly 10,200 Thai baht

2. You have 10,000 Thai baht in a bank account. The interest rate for this account is one percent per year. The price of all goods and services increases by two percent per year. How much can you buy in one year?

   a) Less than I can buy today
   b) More than I can buy today
   c) Exactly as much as I can buy today

3. It is safer to buy one company stock than to buy a stock mutual fund.

   a) True
   b) False

"I don't know" or "I refuse to answer" are admissible answers to all questions.

Table 1

How is financial literacy measured?

Percentage of correct answers in percent

	Bangkok	Germany	USA
Question 1	79	82	65
Question 2	62	78	64
Question 3	23	61	52

Source: Xu, Lisa and Bilal Zia (2012): Financial Literacy around the World, World Bank Policy Research Working Paper 6107.

The survey results for Germany and the US are taken from other studies that were based on the same questions.[10] The results show that the percentage of correct answers for questions 1 and 2 was between 60 and 80 percent in all three countries. Question 3, on the other hand, was answered correctly by fewer than one in four respondents in Bangkok, while in Germany and the US it was answered correctly by 61 and 52 percent of the respondents, respectively (see Table 1).

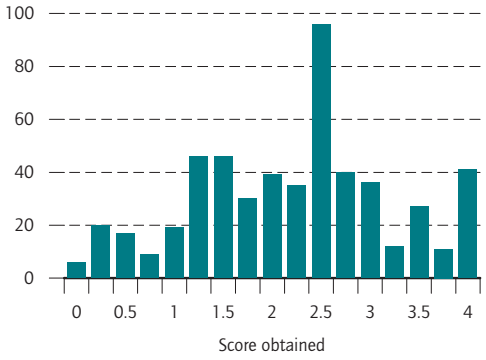
In addition to these questions, which were asked in all three studies, the present study also tested the respondents' familiarity with foreign banks. The question "What foreign banks operate in Bangkok?" was developed as an indicator of specific institutional financial knowledge.

The financial literacy level of individual respondents was calculated based on the number of questions they answered correctly (see Figure 1). One to three points were awarded for the three standard answers; for every foreign bank that was named correctly in response to question 4, an additional quarter of a point was awarded, for a possible total of between zero and one point. Most of the respondents received a score of 2.5 points.

10 Lisa Xu and Bilal Zia, "Financial Literacy around the World," *World Bank Policy Research Working Paper* 6107 (2012). For each survey, the questions are modified to reflect the currency of the country where the survey is being conducted.

Figure 1

Financial literacy level
Number of respondents



Source: Own calculations.

Most respondents achieve 2.5 out of 4 points.

Table 2

Correlations between financial literacy, socio-demographic variables and financial behavior

	Financial literacy
Income (Individual income)	0.174***
Assets (Total financial assets)	0.104**
Education (Highest educational attainment)	0.281***
Age	−0.043
Numeracy (Number of numeracy questions answered correctly)	0.246***
Diversification of financial assets (Number of financial assets)	0.169***

*Significance levels: ***< 1 %, **< 5%, *< 10 %*

Source: Own calculations.

Educational attainment has the strongest link to financial literacy.

Diversification of assets is an indicator of good financial behavior

"Good behavior" is defined here as the diversification of assets across multiple investment types. As every type of investment has its own specific risk profile, it is generally advantageous to diversify assets across multiple investment types. This is, however, only a very rough indicator, as investors' specific portfolios and their personal preferences also play key roles.

The survey included six different forms of assets. Almost all respondents possessed one of these, namely a savings account. Other popular types of investment among the respondents include fixed deposits accounts, stocks (and funds), bonds, insurance products (for investment use), and gold. An indicator of good financial behavior was created by adding the number of investment types used by the respondents (not including savings accounts), resulting in answers with a possible score between 0 and 5. The average score was 0.75, meaning that most respondents have some form of investment aside from a savings account.

Financial behavior is also shaped by socio-economic factors

To filter out the effect of childhood experiences and financial education on financial behavior, other possible factors must also be taken into consideration. The literature contains a number of different variables:[11] financial literacy is higher and financial behavior tends to be better when respondents have higher incomes, greater assets, and higher levels of education. The extent to which age plays a major role is not as clear; however, middle-aged people tend to have the highest level of financial literacy. Numeracy is of particular significance, as people who have an affinity for numbers and calculating find it considerably easier to make financial decisions. This therefore raises the question of the extent to which financial literacy goes beyond basic numerical ability. The present study confirms these results (see Table 2), which indicate that higher income, greater assets, better education, and stronger numeracy are positively associated with financial literacy and financial behavior.

Parents' effect on financial literacy

This study of the middle class in Bangkok uses mediation analysis to show relationships between financial literacy, financial behavior, and other variables. Mediation analysis looks at more than just the effect of X on Y, as is done in more widely used regression analyses. It also takes other (intermediation) variables into account. For example, there may be a case in which X has an effect on M, which in turn has an impact on Y (at least in part). Mediation analysis makes it possible to examine these extended effects and relationships more precisely.

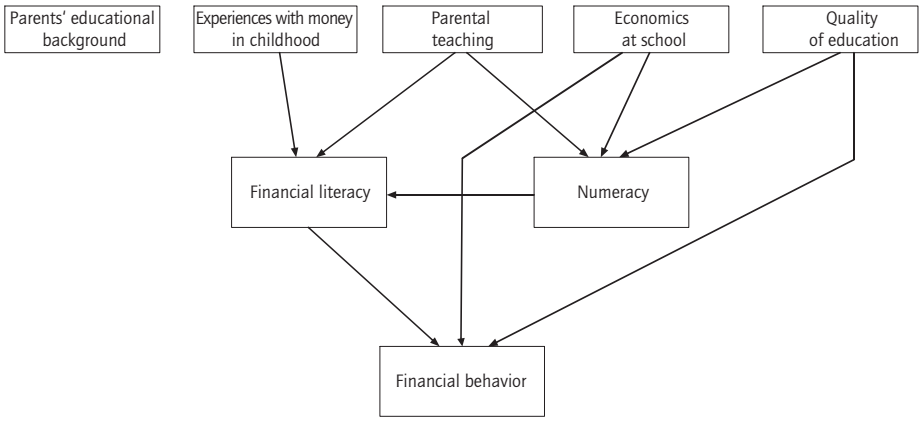
Results show that parental teaching, for instance, whether parents encouraged their children to save or taught them to budget , has a strong impact on financial literacy (see Figure 2).[12] There is also a correlation between

11 Lusardi and Mitchell, "Economic Importance."

12 Figure 2 shows the results of the regression analysis, available on request.

Figure 2

Factors[1] that influence financial literacy and financial behavior



1 Every arrow represents a significant relationship.

Source: Own illustration.

Only economics at school and quality of education influence financial behavior directly.

having experience with money in childhood and financial literacy in adulthood.

Interestingly, none of the other three childhood variables have a direct effect on financial literacy levels. There are, however, indirect relationships between these variables. Both economics in school and quality of education have a positive effect on numeracy. This, in turn, has a positive effect on financial literacy and thus indirectly impacts financial behavior. The results further show that parental educational background has no direct effect on financial literacy and financial behavior.

Financial literacy and school improve financial behavior

In line with results found in the literature, the dataset from Bangkok used here shows that higher financial literacy has a beneficial effect on financial behavior. As parental teaching has a positive impact on financial literacy, it also has an indirect effect on financial behavior of children when they reach adulthood.

Economics in school and educational quality show a direct positive relationship with financial behavior, represented here by greater diversification of assets. They also have an indirect effect since both of these childhood factors affect numeracy, which in turn improves financial literacy.

In conclusion, there are two channels through which financial behavior is impacted. The first is parental teaching, which boosts financial literacy, thus improving financial behavior, and the second is school. Economics in school and quality of education have a direct effect on financial behavior and also lead to improved numeracy, which in turn strengthens financial literacy.

Which of these channels has the greatest impact?

Mediation analysis also shows that parental teaching has the greatest impact on financial literacy. This effect is mediated slightly when numeracy is taken into account, but it remains significant. Parental teaching also has the strongest effect on numeracy of all the factors examined in the present study.

An examination of the factors that affect financial behavior reveals that diversification of assets (defined in this analysis as investments made in addition to savings deposits) increases by approximately 12 percent on average when respondents are able to correctly answer an additional financial literacy question. When respondents studied economics in school, diversification of assets increased by about 13 percent. Educational quality has an even stronger impact on diversification: respondents that were born in Bangkok and completed their highest level of education there have approximately 23 percent more assets on aver-

age than respondents who do not come from Bangkok and did not complete their highest level of education in this city.[13]

When examining the strength of the different effects, it becomes apparent that education and parental teaching have a considerable impact. Beyond that, we should be careful not to interpret the strength of the various effects too broadly, as they vary with the specific survey (group of respondents, variables used, etc.).

What policies are available?

Many OECD countries, as well as many developing and emerging countries, are making efforts to introduce financial education. This may appear to be an obvious way to improve financial literacy, but there are alternatives. It would be possible to reduce the number of decisions that people need to make, for example by introducing mandatory insurance, thus reducing the need for voluntary private insurance.

There are many ways to improve financial literacy. Based on the present study, there are at least four possible instruments worth considering:

1) Improving general numeracy in school proves useful in many areas of life and, among other things, helps to improve financial literacy (as it is typically measured).
2) From an even broader perspective, we can say that generally higher levels of education in society at large have positive side-effects: they boost financial literacy and thereby improve financial behavior.
3) One clearly effective approach to improving numeracy and consequently financial behavior is economics in school. The current trend is to favor measures that teach financial literacy directly, either by integrating the appropriate modules into school curricula, as in Baden-Württemberg, which now offers economics as a separate subject, or through special training. The special training courses, however, are currently being offered only in some schools as pilot programs and are not yet widespread. One of these initiatives is "My Finance Coach", which provides financial training in German schools.[14] In developing countries, financial training is provided by Freedom from Hunger, among other organizations.[15]
4) Another valuable approach would be to raise parents' awareness of the key role they can play in teaching their children about money. It should be noted that this does not require any advanced knowledge on the parents' part. Indeed, it is basic principles, such as saving and budgeting, that are most helpful. For example, family centers or initiatives such as the British PEEP (Peers Early Education Partnership) programs could be used to make parents aware of the advantages of teaching their children about money.

Conclusion

The present study shows that family background has a major impact on financial literacy levels and, through financial literacy, has a knock-on effect on financial behavior. In addition, certain school-related factors (quality of education and the teaching of economics in school) directly and indirectly promote broader diversification of assets and consequently sound financial behavior. Family and school complement each other in their effect on financial behavior.

On the whole, however, the current state of research does not give cause for great optimism. Introducing government policies to influence how parents raise their children is likely to be difficult. When we consider education, changes in schools generally, such as improving quality or introducing economics as a separate subject, are effective but also costly.

A more targeted approach is provided by financial literacy training programs, which were not part of this study. Unfortunately, the available evidence on the effect of these training programs tends to be disappointing.[16] The effectiveness of programs has been shown to vary widely.. A systematic evaluation of what leads to this variety in effectiveness is still in the early stages.[17] There is reason to believe that training programs can be designed successfully, even if we do not currently know enough to say exactly how best to approach this.

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13 The variable "born in Bangkok/highest educational attainment in Bangkok" is used as a proxy for level of education, which is higher on average in Thailand's large cities than in its rural areas.

14 My Finance Coach, accessed June 22, 2015, http://www.myfinancecoach.de.

15 Freedom from Hunger, accessed June 22, 2015, https://www.freedomfromhunger.org/education-modules.

16 Fernandes et al., "Financial Literacy."

17 Margaret Miller, Julia Reichelstein, Christian Salas, and Bilal Zia, "Can You Help Someone Become Financially Capable? A Meta-Analysis of the Literature," *World Bank Research Observer* (forthcoming).

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SEVEN QUESTIONS TO ANTONIA GROHMANN

»Many people have inadequate understanding of basic financial concepts«

1. Ms. Grohmann, some people make considerably poorer financial decisions than others. Where exactly do these people experience difficulties? Many individuals make poor financial decisions, particularly when it comes to saving for retirement. They don't start planning early enough and consequently don't save enough to provide them with financial security in old age. They underestimate how much money they'll need when they retire and how long they'll live and so fail to put sufficient funds aside. Another problem for some people is that they run up too much debt. In terms of financial investments, we see the main type of asset most people invest in is an owner-occupied property or they own stocks in the company they work for, whereas a more diversified portfolio would be more sensible.

2. What are the reasons for poor financial behavior? Many people's financial literacy is too limited and they have an inadequate understanding of concepts such as interest, inflation, or risk diversification. One reason for this could be poor numeracy skills or that their parents failed to teach them how to manage money at an early age. Poor schooling might be another reason.

3. Which factor has the greatest impact? Our study focuses specifically on childhood variables. This enables us to demonstrate that people whose parents encouraged good financial behavior at a young age are more financially literate and have a better grasp of financial concepts. Our study also shows that a better education generally and studying economics in school have a positive impact on financial behavior.

4. What are the financial literacy levels among the German population? There are certainly people who have an insufficient understanding of basic financial concepts. The problem is that these people are often precisely those who need this knowledge the most, in other words, low-income groups with a limited school education.

5. All German Länder have now integrated financial education into the school curriculum. What impact has this had? In my view, it's still too early to answer this with 100 percent certainty. It will only become evident when the students whose education included financial studies reach adulthood. Only then will there be any clear findings. However, there are short-term scientific studies on school students which demonstrate that financial education in school improves financial literacy. Yet the studies also show that these school courses have no impact on saving behavior.

6. What form should financial education take in Germany? Studies have shown that teaching simpler concepts or rules of thumb is often more effective than desperately trying to explain how to calculate an interest rate. How to structure these courses and financial education in general definitely requires more research. It certainly makes sense, however, to teach school-age children how to manage their own finances. School is essentially the only place where policy-makers can still reach everyone with relative ease. It's clearly much more difficult to influence how parents raise their children. Although there are certainly potential ways of drawing parents' attention to the fact that financial literacy is crucial for their children's future financial behavior, whether or not they actually do anything about it is quite another question.

1. What is the situation in other countries? Other countries face a similar predicament. On the whole, financial products have become increasingly complex and are difficult to understand. Additionally, social security systems in countries such as the US and also in Europe have been subject to more and more cutbacks. Consequently, the individual is now expected to bear the primary responsibility of putting money aside for their own retirement, for example. In my view, this is a trend that can be observed in many industrialized nations. The financial products available in developing countries, however, are far more straightforward. Nonetheless, financial literacy is still important in these countries to ensure that people know how to manage these products properly.

Interview by Erich Wittenberg

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 spending[2] show a more significant decline during the crisis[3] 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 *(Kostenstrukturerhebung 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]

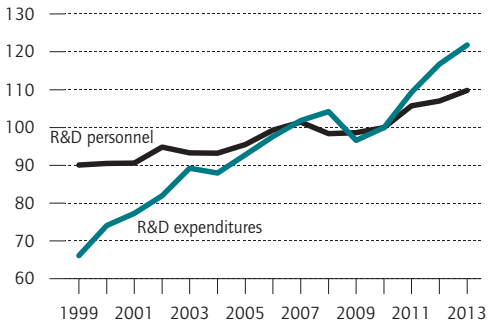
The following statements are based on special analyses by the Federal Statistical Office for the manufacturing sector (excluding mining) for the reporting years 1999 to 2013. This allows the development before, during, and after the crisis years of 2008 and 2009 to be examined. The years 2004 to 2007 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 economic 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).

Figure 1

R&D expenditures and R&D personnel in manufacturing industry
2010 = 100



Source: Federal Statistical Office, calculations by DIW Berlin.

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

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

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 dieDeutsche 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).

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.

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 employees[9]), too, spending 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 percent 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.

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 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.

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 Cyclicality 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.

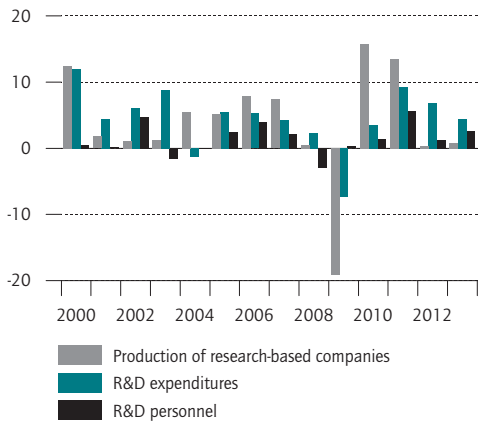
strategic plans and viewed R&D as a long-term investment.[13] Companies might also have responded to demand fluctuations by outsourcing R&D activities or reintegrating them again (insourcing).

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.

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.

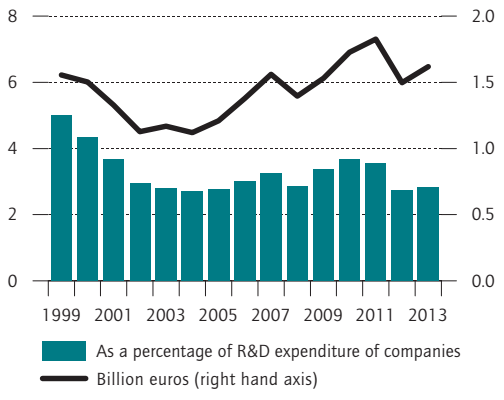
tion—after the crisis, however, the reverse was true. Major companies exhibit a similar pattern to that observed in the research-intensive industries. SMEs expanded their spending on research and development during the crisis, despite declining demand.

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 government[14] 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.

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.

matically.[15] This took the government cofinancing rate for SMEs to an estimated ten percent[16] 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.

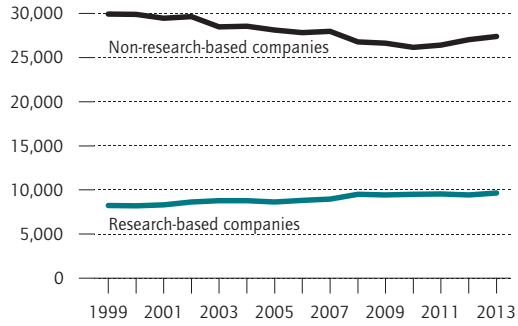
15 The additional funds amounted to 53 million euros in 2009, to 320 million euros in 2010, and to 397 million euros in 2011. See BMBF (pub.), *Federal Report on Research and Innovation 2014* (Berlin: 2014), 444.

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.

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

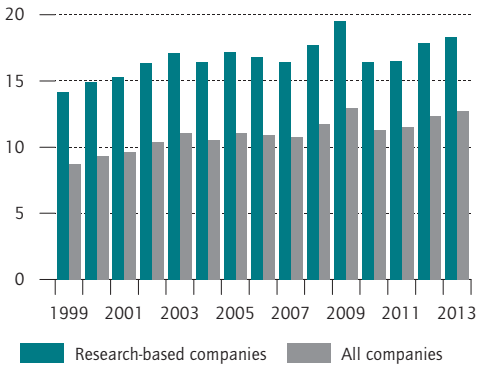
	2008 compared to 2004	2010 compared to 2008	2013 compared to 2010
Manufacturing total[1]	2.0	−0.1	0.6
R&D-intensive branches	−0.1	−0.4	0.2
Chemical and pharmaceutical products[2]	−0.2	0.0	1.1
Pharmaceutical products[3]	.	−1.6	5.4
Mechanical engineering[4]	1.6	−0.6	−1.0
Manufacture of motor vehicles, 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.

Figure 5

R&D intensity in manufacturing industry
R&D expenditures as percent of value added



Source: Federal Statistical Office, calculations by DIW Berlin.

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.

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 percent[18] 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.

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

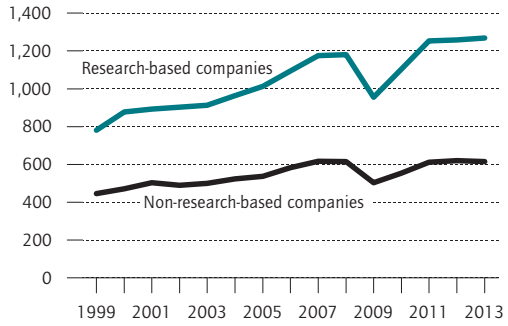
1–9 Definition of sectors see table 1.

Source: Federal Statistical Office, calculations by DIW Berlin.

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.

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

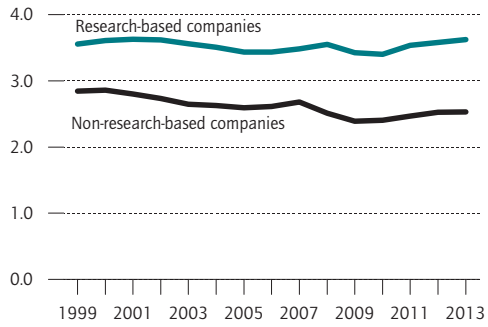
	2010	2011	2012	2013	2008 less 2004	2010 less 2008	2013 less 2010
Manufacturing total[1]	66.6	67.2	67.0	67.4	1.0	0.8	0.8
R&D-intensive branches	85.6	85.8	85.2	85.4	0.1	1.0	−0.2
Chemical and pharmaceutical products[2]	81.4	81.2	79.4	80.3	−0.4	1.7	−1.1
Pharmaceutical products[3]	76.4	75.7	76.9	77.9	.	−4.7	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.

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.

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 expenditures[1] 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.

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 funding 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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