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AT A GLANCE

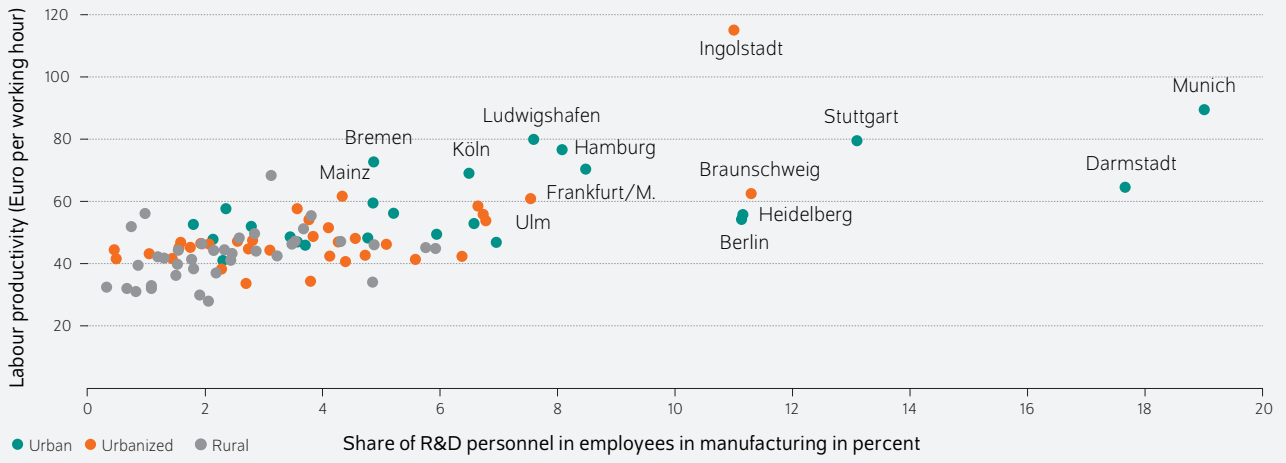
Research and productivity – manufacturing companies in cities have an advantage

By Heike Belitz and Alexander Schiersch

- Analysis of an extensive data set on German manufacturing companies shows that companies with R&D activities and located in central urban regions are especially productive
- The regional research systems in major urban regions vary greatly
- This makes specific research and technology policy support for the knowledge transfer between local companies and research institutes necessary
- For new measures on the federal level, such as the transfer initiative for companies included in the recent coalition agreement, the varying regional effects should be considered early on

Companies in urban regions are on average more R&D intensive and more productive than companies in urbanized and rural regions

Labour productivity and R&D intensity in the manufacturing sector by spatial planning regions in 2015



Sources: SV Wissenschaftsstatistik, VGRdL; authors' own calculations.

FROM THE AUTHORS

Manufacturing firms in agglomerations have a higher productivity than companies in peripheral or rural regions.
— Alexander Schiersch, study author —

Companies in cities benefit from the knowledge that is generated by universities, research institutes and other companies.
— Heike Belitz, study author —

Research and productivity – manufacturing companies in cities have an advantage

By Heike Belitz and Alexander Schiersch

ABSTRACT

Companies invest in research and development (R&D) to safeguard their competitive ability and increase productivity. Using extensive company data for Germany, the study shows that manufacturing companies that engage in R&D activities and that are located in a central urban agglomeration are especially productive. They additionally benefit from knowledge created by R&D activities of other companies and public research. However, the regional research systems in major urban regions are very different. These differences require tailored support by research and technology policy for the development of regional research and innovation systems on a region-by-region basis. The goal should be to reinforce the regional transfer of knowledge among companies, universities, and non-university research institutes. Regional differences must be taken into account when devising policy because uniform programs on the federal level will have different effects depending on the research region.

Germany's manufacturing sector comprises more than 23 percent of the country's added value, which means in international comparison it has an above-average significance for the country's economic output. Among individual companies, however, there are clear differences. For the most part, their productivity is driven by technological progress and in-house investment in research and development (R&D). The regional environment also plays a role. Urban agglomerations have a number of advantages that could increase the success of the companies located in them. The advantages range from availability of knowledge and highly qualified specialists to the spatial concentration of customers and access to larger markets at lower transport costs. Alongside its own R&D, company productivity is thus influenced by the economic and demographic structure of its region.

In the first section of the present study, extensive official data for manufacturing companies in Germany was used to examine whether regional characteristics have an influence on their productivity, in addition to their investment in R&D. Both the level of urbanization and location of the region were considered. The second section compares the various R&D capacities of the regions in Germany in the private and public sectors, as well as their technological orientation, based on regional data on R&D personnel and patent applications. The leading urban regions in which industrial research is concentrated are the focus of the study; exemplary here is Berlin, as it has recently caught up a little to the other regions in Germany. The unit of investigation is the spatial planning region (Raumordnungsregion, ROR).[1]

Total factor productivity of industrial companies highest in urban regions

The regional economic literature postulates that the advantages of urban agglomerations lead to higher corporate productivity. Data for manufacturing companies was used to verify whether or not this can be confirmed. In the first

1 Spatial planning regions are administrative or (at least partially) functional regions for analysis and policy recommendations. In Germany, they are defined by the BBSR. The country's 96 spatial planning regions are between districts and administrative districts and in general, respect the borders between the German states. Also see BBSR.

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step, micro data from the official statistics were used to calculate the companies' total factor productivity (TFP). TFP is a measure of productivity used as an indicator for the technological capacity or the total efficiency of all factors used in production. TFP is highly correlated with labor productivity but contrary to the latter, it is not distorted by production's capital intensity.

We linked the estimated TFPs to two key spatial indicators of the Federal Institute for Research on Building, Urban Affairs and Spatial Development (*Bundesinstitut für Bau-, Stadt- und Raumforschung*, BBSR) in order to study the relationship between spatial characteristics and productivity.[2] The first key indicator has three possible values and measures a region's level of urbanization.[3] The second one measures the region's location and has four possible values ranging from "very central" (e.g., Munich) to "very peripheral" (e.g., a rural municipality in Western Pomerania).[4] These two characteristics of regions differ despite some overlaps, since there are also spatial concentrations of companies in regions with low population density.

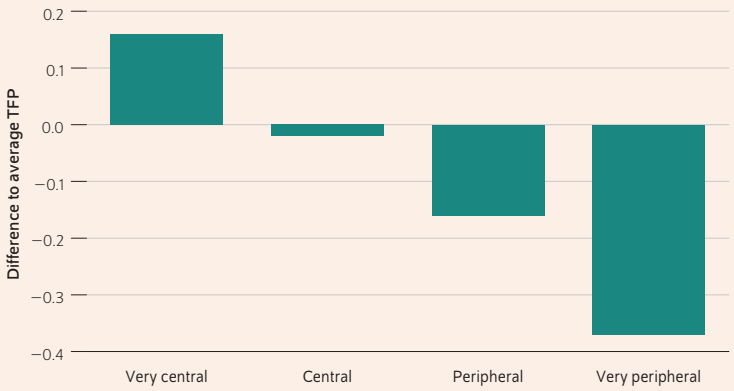
It is presumed that the TFP of companies in urban and very central regions is higher than in rural or very peripheral regions. A simple graphical comparison of unweighted means of TFP values confirms this (see Figures 1 and 2). The figures show the distance to the average value for Germany (differences between the mean of logarithmized TFPs, approximately equal to the percentage difference).[5] The average TFP of companies in very central locations is thus significantly higher than the German average and also much higher than the average TFP of companies in peripheral or very peripheral locations (see Figure 1). The expacted difference can also be found in the second figure. Companies in urban regions are on average considerably more productive than companies in rural regions (see Figure 2).

These descriptive results do not permit conclusions about the strength or significance of the relationship among the TFP, spatial structure, and location since other influencing factors, such as the effect of the business cycle, are not considered. And a company's productivity is likely to be strongly influenced by its R&D activity. Moreover, companies with research activities are more likely to be found in urban regions with a dense population of highly qualified specialists, universities, and non-university research institutes. The above-average TFP in urban regions could thus also be driven by company investing in R&D.

Figure 1

Log-difference in average total factor productivity between regions (types of locations)

Manufacturing industry, Years 2003–2014, equals approximately percentage differences divided by 100



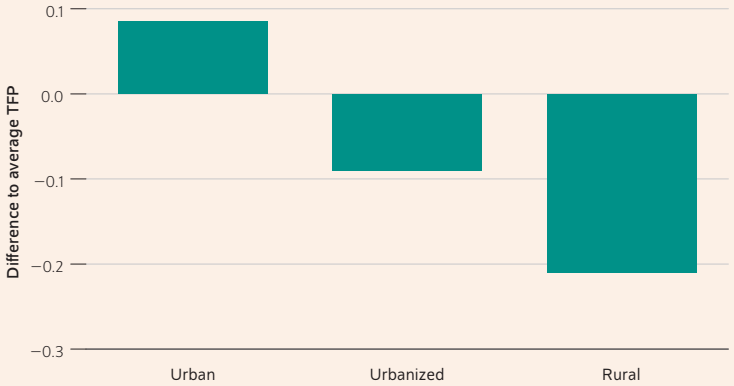
Sources: BBSR (Federal Institute für Research on Building, Urban Affairs and Spatial Development); Research Data Centre of the Statistical Office; AfiD Panels manufacturing firms; authors' own calculations.

Companies in central regions show an above average productivity.

Figure 2

Log-difference in average total factor productivity between regions (level of urbanization)

Manufacturing; Years 2003–2014, equals approximately percentage differences divided by 100



Sources: BBSR (Federal Institute für Research on Building, Urban Affairs and Spatial Development); Research Data Centre of the Federal Statistical Office; AfiD Panels manufacturing firms; authors' own calculations.

Companies in urban regions show an above average productivity.

2 The data are available on the municipality level.

3 The key indicator "settlement structural characteristic" (*siedlungsstrukturelle Prägung*) is based on the settlement structural parameters of population density and the proportion of settled surface area.

4 The BBSR determines the key "location" indicator using an accessibility analyses. Commuter flow is the key factor here. This also takes a region's economic importance into consideration. For detailed information on the two key indicators and on the allocation of each by municipality, see Bundesinstitut für Bau-, Stadt- und Raumforschung, (in German; available online, accessed on October 16, 2018).

5 The values are calculated as the difference between the average logarithmized TFP of all companies in the data set and the average logarithmized TFP of the companies in the respective regions. For smaller values, the "log difference" equals the percentage difference between two variants. To be precise, two points in the figure are contrasted as follows: $\ln(TFP_a) - \ln(TFP_b) = c$ or $TFP_a = e^c TFP_b$. The TFP of companies in very central regions is therefore $e^{0,18}$ or roughly 20 percent greater than the German average.

Table 1

Ordinary-least-squares estimation of the correlation between total factor productivity and spatial density

	Dependent variable: total factor productivity			
	(1)	(2)	(3)	(4)
Very central	–			–
(Reference group)				
Central	−0.176***			−0.0336***
	(0.00519)			(0.00118)
Peripheral	−0.314***			−0.0486***
	(0.00556)			(0.00156)
Very peripheral	−0.528***			−0.0569***
	(0.0122)			(0.00290)
Urban		–		–
(Reference group)				
Urbanized		−0.175***		−0.00835***
		(0.00567)		(0.00126)
Rural		−0.295***		−0.00587***
		(0.00592)		(0.00142)
R&D			0.536***	0.111***
			(0.00426)	(0.000913)
Time effects				Yes
Industry effects				Yes
Federal states effects				Yes
Constant	7.127***	7.056***	6.736***	5.728***
	(0.00353)	(0.00276)	(0.00282)	(0.00327)
Observations	174,860	174,860	174,860	174,860
R^2	0.024	0.016	0.083	0.963

Sources: BBSR (Federal Institute für Research on Building, Urban Affairs and Spatial Development); Research Data Centre of the Statistical Office; AfiD Panels manufacturing firms; authors' own calculations.

Level of significance: * p<0.1, ** p<0.05, *** p<0.01

Therefore, the relationship among the key regional indicators, R&D activity of individual companies, and the additional explanatory variables is verified using a simple regression analysis (see Table 1). The urban or central regions serve as reference group in the estimations. According to economic theory and the findings presented (see Figures 1 and 2), on average the TFP of companies in peripheral areas must be lower than that of companies in central locations. Further, companies in rural regions should have a lower TFP than those in urban regions. In the estimations, these relationships should show up in the form of negative coefficients. And the magnitude of the negative coefficients should also increase with increasing distance to the urban agglomeration.

The results of the regression analyses confirm the expected relationships (see Table 1). First, the more peripheral or rural a company's location, the lower its TFP (see Columns 1 and 2). Second, in-house R&D activities are a key determinant of TFP (see Column 3). Assuming the absence of additional influencing variables, companies with own R&D activities have a TFP that is around 70 percent higher.[6] When all explanatory variables have been taken into consideration (see Column 4), the basic relationship remains. In other words, a company in a less densely populated area has a lower TFP than a similar company in a very central location. Yet, the differences between the locations are now much smaller than they were in the simple comparison (see Columns 1 and 2 or Figures 1 and 2). For example, the TFP of a company in a very peripheral area is now around six percent lower than the TFP of a company in a very central location.

However, a company's own R&D activities remain a key influencing variable. Companies that engage in research and development (measured as a binary variable) have a 11 percent higher productivity than companies located in the same type of region but without R&D activity.

Companies with strong investment in R&D in urban or central areas benefit the most from the advantages of urban agglomerations – such as knowledge transfer – resulting from the R&D activity of other companies and public research.

R&D in regions...

concentrated in manufacturing on urban regions

Around 60 percent of corporate researchers are employed in urban regions that account for around half of all employed people and only 40 percent of people employed in the manufacturing sector.[7] Half of the business R&D personnel are located in only 11 of 96 spatial planning regions, which include nine urban regions and two urbanized regions. Stuttgart and Munich, where one-fifth of all researchers in the German business enterprise sector y are employed, are at the top of the ranking by a clear margin.

R&D intensity is measured by the proportion of business enterprise R&D personnel among all employed people. Ingolstadt has the highest R&D intensity, followed by the Darmstadt and Stuttgart regions (see Table 2).[8] The majority of company R&D in Germany takes place in the manufacturing sector, which employs 80 percent of R&D personnel. And the R&D personnel in the scientific research and development service sector (five percent) probably conducts most of its research for the manufacturing sector. Since the majority of R&D takes place in and for manufacturing industry, it is possible to approximate the R&D intensity of regional manufacturing sector using the ratio of business R&D personnel in a region to the number of employees in

6 The percentage difference (deviation) in semilogarithmic functions is given by exp $(\beta - 0{,}5 * V(\beta)) - 1$. Peter E. Kennedy (1981). "Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations." American Economic Review 71 (4), p.801.

7 With regard to R&D personnel in the private sector, the data for spatial planning regions (ROR) are based on special analysis of the Wissenschaftsstatistik of the Stifterverband, a company collecting data on private research activities in Germany. The figures on employed persons were acquired from the data on rural districts in the Regional Accounts (*Volkswirtschaftlichen Gesamtrechnung der Länder*, VrGL).

8 To improve recognition, some planning regions are designated by central city instead of using the BBSR designation. For example, Darmstadt stands for the Starkenburg planning region.

this sector (see Table 2). In this assessment of the research intensity of manufacturing companies, the Munich region ranks first. Berlin (no. 6) and Frankfurt/Main (no. 8) also have a relatively R&D-intensive manufacturing , which is not discernible when looking at the ratio of R&D personnel in companies to all employed people, where they show up as no. 18 and no. 14 respectively. Conversely, some regions also descend in the ranking when the focus is R&D intensity in the manufacturing sector : Ingolstadt went from no. 1 to no. 7 and Heilbronn from no. 7 to no. 14, for example (see Table 2).

Universities and non-university research institutions

University research personnel are distributed among the various types of areas to a similar extent as they are among companies: a good 60 percent of the R&D employees in these fields work in urban regions. And almost 70 percent of R&D personnel in non-university research institutes are located in cities. However, private and public research in individual regions have a very different significance. Strong industrial research is not supported by strong public research everywhere.[9]

The third-largest research region in Germany, Berlin, is characterized by a high proportion of research in the public sector. The capital has the most R&D employees in government research institutes and after Munich, has the second largest number of university-affiliated researchers (see Figure 3). Among the strongest research regions in Germany, with a proportion of 70 percent of R&D personnel in the public sector (government research institutes and universities), only Aachen has a higher proportion than Berlin (60 percent), followed by Hamburg (47 percent).

Significant growth of R&D jobs in cities

Between 2003 and 2015, the R&D personnel in both public and private sector grew by around 35 percent. In some strong research regions (Stuttgart, Heilbronn, and Braunschweig), the growth occurred in the private sector. In other regions, the number of R&D personnel expanded in all three sectors: private, government research institutes, and universities. In Berlin, the number of R&D personnel grew primarily in the public sector and the business enterprise sector made the lowest contribution (see Figure 3).

In recent years, absolute growth in R&D personnel was highest in urban regions (see Figure 4). Over time, it has also grown in urbanized regions as well. Most recently the expansion in R&D personnel has been increasingly driven by (manufacturing) companies.

In comparison to regions where research abounds, the R&D personnel in companies in Berlin has shown the weakest growth since 2003 – paralleling Munich and Darmstadt (see

Table 2

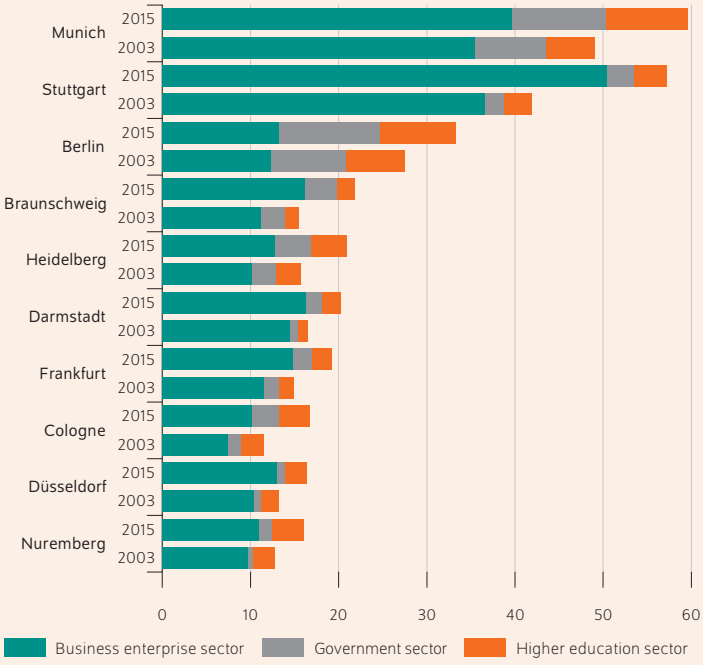
R&D personnel of companies in the spatial planning regions with strongest research in Gemany 2015

	Type of region	Share of region in R&D personnel	Share of R&D personnel in employment			
			Total	Manufacturing	Total	Manufacturing
		Percent			Rank	
Stuttgart	urban	12.5	3.2	13.1	3	3
Munich	urban	9.8	2.2	19.0	5	1
Darmstadt	urban	4.0	3.2	17.7	2	2
Braunschweig	urbanized	4.0	2.8	11.3	4	4
Frankfurt	urban	3.7	0.9	8.5	14	8
Berlin	urban	3.3	0.7	11.1	18	6
Düsseldorf	urban	3.2	0.8	5.2	17	18
Heidelberg	urban	3.2	2.0	11.2	8	5
Nuremberg	urban	2.7	1.4	6.6	11	15
Heilbronn	urbanized	2.5	2.0	6.7	7	14
Cologne	urban	2.5	0.8	6.5	16	16
Ingolstadt	urbanized	2.3	3.3	11.0	1	7
Hamburg	urban	2.1	0.7	8.1	20	9
Ludwigshafen	urban	1.9	1.8	7.6	10	10
Bielefeld	urban	1.7	0.8	3.5	15	20

Sources: SV-Wissenschaftsstatistik; authors' own calculations.

Figure 3

R&D personnel of the 10 spatial planning regions with the highest research output by sectors
Full-time equivalents; years 2003 and 2015



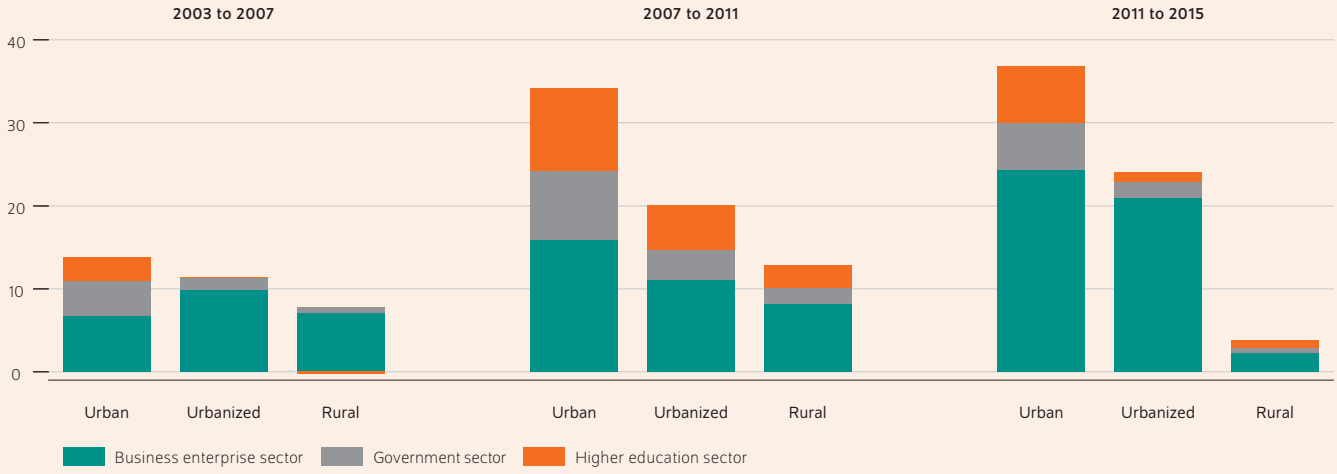
Sources: German Statistical Office, SV-Wissenschaftsstatistik; authors' own calculations.

Berlin and Munich have the most researchers in the public sector.

9 Also see Alexander Eickelpasch, "Private R&D Not Necessarily Drawn to Areas with High Public R&D," *DIW Economic Bulletin* no. 45 (2016): 517-526 (available online).

Figure 4

Increase in R&D personnel by sectors and types of regions
Full-time equivalents; Years 2003–2015



Sources: German Statistical Office, SV-Wissenschaftsstatistik; authors' own calculations.

Most new R&D jobs are created in urban regions.

Figure 5). However, the initially dramatic decline in R&D personnel was halted in 2007. At that point in time, the downswing turned around and since then, the number of R&D personnel in companies in Berlin has grown at a pace met only by Stuttgart and Braunschweig. In the latter cities, however, growth was driven more strongly by major corporations – particularly in the automotive sector – than in Berlin. In Berlin, small and medium-sized companies have a higher share on total R&D investments than SMEs in the six comparative German cities.[10] The major corporations with 1,000 and more employees in Berlin had a share on private R&D expenditure of just under 57 percent, while in the comparative regions that share was at almost 84 percent.[11]

High-tech research in Berlin and Munich extremely diverse

Some of the R&D activity in companies and some public-sector research institutes in natural sciences or technical fields results in patent applications .[12] Patents can be classified to a region based on the address of both the applicant and the inventor. While classification by inventor address gives information on the place of invention, and thus the researcher's workplace, in the case of companies the applicant's address is often the company's headquarters. This is why patents by inventor place of residence were used to assess research capacity by region.[13]

Since patent data also contains information about the technology of the invention, it is possible to create technological profiles of the regional R&D. The technological specialization of the spatial planning regions by high-tech field was studied here based on regional patent applications to the European Patent Office (EPO) by inventor place of residence. Both the OECD and Eurostat provide regional patent data. The OECD differentiates among five high-tech fields: biotechnology, information and communication technologies, pharmaceuticals, medical technology, and nanotechnology.[14] Eurostat relies on a different definition from the three major patent offices of Europe, the U.S., and Japan for high-tech fields and presents data for six high technologies: aviation technology, communication technology, computer technology, lasers, microorganisms/genetic engineering, and semiconductors.[15] The data are available for the period up to 2012.

The number of patent applications to the EPO with inventors in Germany has remained approximately the same within the study horizon. The proportion of patent applications in

10 The comparative regions encompass the core cities (urban regions) and the immediate suburbs of the six major cities: Hamburg, Munich, Cologne, Frankfurt, Stuttgart, and Düsseldorf.

11 Julian Kahl, "Innovationserhebung Berlin 2016 – Innovationsverhalten der Berliner Wirtschaft," Technologiestiftung Berlin (2017) (available online).

12 One current assessment of patent applications in the regional clusters with the most patents worldwide showed that companies apply for the majority of patents. The share of universities and public-sector research institutes is greater than ten percent in only a few clusters. Among the German patent clusters, at 12 percent the proportion in Berlin is the highest. Kyle Bergquist, Carsten Fink, and Julio Raffo, "Identifying and ranking the world's largest clusters of inventive activity," *WIPO Economic Research Working Paper*, no. 34 (2017) (available online).

13 If the number of patent applications by applicant address exceeds the number of inventor addresses, this means that many headquarters of major corporations are located in one region. This applies to Munich, Stuttgart, and Düsseldorf. On the contrary, Berlin, Nuremberg, and Karlsruhe are the regions with many patents but weak representation of major corporations' central management functions.

14 OECD, Patents by regions (available online, accessed on June 1, 2018).

15 Eurostat, Patent applications to the EPO at regional level (available online, accessed on June 1, 2018).

the selected high-tech fields according to the OECD definition was 35 percent in 2012, and according to the Eurostat definition it was only 13 percent.

Since R&D personnel are concentrated in urban regions, most patents were applied for by inventors in these regions (56 percent). As expected, the proportion of urban areas in high-tech patents according to the OECD definition is somewhat higher at 62 percent and in the Eurostat definition, at 67 percent. The ten planning regions with the most patents in Germany are all urban regions (see Table 3). At the top of the ranking in 2012, Stuttgart and Munich were the strongest research regions. However, the ranking changed when we look at high-tech patents. In Munich, Berlin, and Heidelberg, the proportion of patent applications in high-tech fields is significantly higher than the share in all patents according to both definitions. In Stuttgart and Düsseldorf, the converse is true.

Regional specialization in the selected high-tech fields was measured by relative patent share (RPS). To calculate the RPS, a region's share of patent applications for a technology field was compared to its share of all patent applications in Germany. The measuring unit "relative patent share of patents p in technology field t in planning region r (RPA_{tr})" indicates whether or not a region has a higher share (positive value) or lower share (negative value) of the patents applied for in technology field t than the total patents.[16]

In both classifications, specialization in high-tech fields is particularly high in Berlin, Heidelberg, and Munich (see Figure 6). On the contrary, other strong research regions such as Stuttgart, Düsseldorf, Cologne, and Bielefeld are not specialized in these high-tech fields. Regional technology profiles have hardly changed since the beginning of the 21st century.

Berlin has the most specialization advantages in the high-tech fields examined here, namely, in ten of the 11 technology fields from the combined OECD and Eurostat classifications (see Table 3). In other words, Berlin has the highest diversity of high-tech research in comparison to the regions with the most patents, followed by Heidelberg (specialization in seven technologies). The variety of high-tech research in Bielefeld, Stuttgart, and Düsseldorf, on the other hand, is comparatively low.

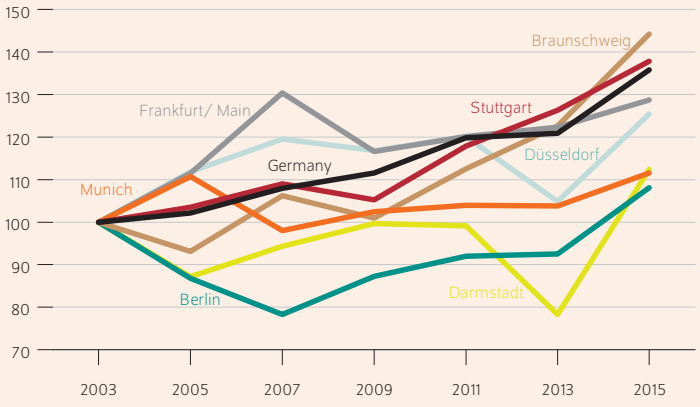
Conclusion: strengthen regional transfer of knowledge among companies, universities, and non-university research institutes

Manufacturing companies that invest in their own R&D boost their productivity. These Companies furthermore benefit from the advantages of urban agglomerations: for example, knowledge transfer via the R&D activity of other companies and public-sector research in close spatial proximity.

Figure 5

Change in R&D personnel of companies in regions with strong research 2003–2015

Spatial planning regions with R&D personnel of more than 13,000 (full-time equivalents) in companies in 2015.



Sources: SV-Wissenschaftsstatistik; authors' own calculations.

Since 2007, the R&D personnel of companies in Berlin is growing again.

Table 3

Spatial planning regions with the most patent applications at the EPO in Gemany 2011/12

	Shares in patent applications			Specialized in high-tech fields	
	Total	High-tech			
Spatial planning region	EPO applications	According to OECD	Eurostat	OECD	Eurostat
	Percent			Number	
Stuttgart	7.7	6.0	6.4	1	2
Munich	7.2	10.6	13.5	2	4
Düsseldorf	4.2	2.9	2.4	2	1
Frankfurt	4.2	6.4	4.3	4	2
Nuremberg	3.8	4.7	5.9	2	3
Berlin	3.1	5.7	5.7	5	5
Heidelberg	2.7	4.1	5.3	4	3
Cologne	2.6	2.0	1.8	3	2
Bielefeld	2.1	1.1	1.1	0	0
Karlsruhe	2.1	2.2	2.3	1	3
Selected regions total	39.7	45.7	48.8	–	–

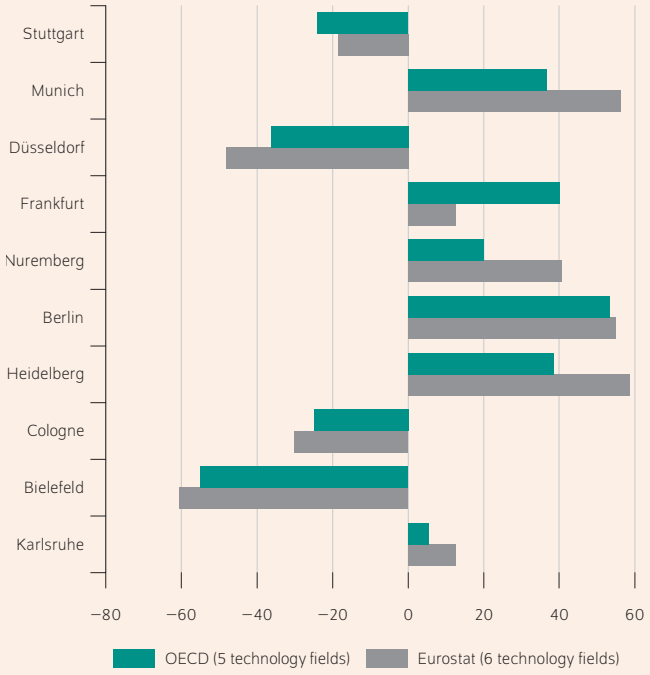
Sources: OECD, Eurostat; DIW Berlin calculations.

16 RPS is calculated and converted to ensure that the values are between -100 and 100:
$\mathrm{RPA}_{tr} = 100 \times \tanh ln\left((p_{tr}) / \sum_r p_{tr}\right) / \left(\sum_t p_{tr} / \sum_{tr} p_{tr}\right)$.

Figure 6

High-tech specialization of the spatial planning regions with the highest patent output 2011/12

Relative patent advantage (RPA), measured between −100 and 100



Sources: OECD, Eurostat; authors' own calculations.

The research regions Berlin, Munich, and Heidelberg are specialized in high-tech.

In urban regions, on average companies conduct more R&D and are more productive than in urbanized and rural regions.

However, urban regions in Germany vary when it comes to the scope and intensity of research in private sector, in the public sector, and with regard to technological profile. Due to their extensive company R&D, Munich and Stuttgart are clearly at the top of the research ranking by region, followed by Berlin, which along with Munich has the most researchers in the public sector (universities and non-university research institutes). And unlike Stuttgart, Berlin and Munich specialize in high-tech research and are highly diversified as well. The R&D personnel that works in and for manufacturing has developed more dynamically in Stuttgart and Berlin than in Munich in recent years. In Berlin, private research resumed its growth in 2007, although major corporations contributed significantly less to this than they did in comparable regions. These differences among urban regions strong in research require support from individual research and technology policies aimed at developing region-specific research and innovation systems. The goal must be to reinforce the regional transfer of knowledge among companies, universities, and non-university research institutes. With its new transfer initiative, the federal government plans to "...support companies as they implement the results of scientific research in products and processes."[17] The initiative must account for regional differences, as federal-level programs have different impacts on the implementation of R&D results in companies.

17 See "Ein neuer Aufbruch für Europa. Eine neue Dynamik für Deutschland. Ein neuer Zusammenhalt für unser Land," Coalition agreement among CDU, CSU and SPD, (2018) (in German, available online).

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LEGAL AND EDITORIAL DETAILS

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