5

Germany

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5.1 Introduction

The transfer of knowledge and technology is a key task of publicly financed research in Germany. This chapter analyzes the structures and processes for such transfer, based on a review of scholarly literature as well as original qualitative and quantitative research.

Germany is a federal republic, and some major governmental tasks, including science and education, are administered at the level of each state (*Land*; plural *Länder*). Germany's sixteen states thus administer their own education systems, including universities and other institutions of higher education (HE). As a result, the public science landscape in Germany is very diverse.

Universities and other HE colleges are not the only significant research organizations in Germany. In addition, the governments of the Länder and the federal government maintain a number of important public research institutes, some of which are much more focused on science and knowledge transfer than universities and other HE colleges are. The Fraunhofer Association in particular engages in highly industry-relevant research, and the Helmholtz Association, the Max Planck Association, and the Leibniz Association are also important players in public science. These institutions are supplemented by a number of public research institutes financed by the Länder.

Because the public science and education system is decentralized across the sixteen states, there is a dearth of centrally collected data about knowledge transfer. This chapter draws on several different sources but only a few official public statistics; most data were collected manually from the Internet, academic publications, and various policy reports, mostly published only in German.

The chapter is structured as follows. In Section 5.2, we outline the German landscape of public scientific organizations. This is followed in Section 5.3 by a discussion of common channels of knowledge transfer. Section 5.4 discusses policies designed to enhance science and knowledge transfer, while Section 5.5 reviews the main findings of the scholarly literature concerning knowledge transfer in Germany. We then present our own research findings from interviews with selected university knowledge transfer offices (KTOs) and policymakers as well as results from a survey sent to all KTOs at German universities. A final section summarizes our conclusions.

5.2 The Role of Universities and Public Research Institutes in Germany's National Innovation System

According to the German Federal Statistical Office,[1] the higher education system consisted of 427 institutions in 2014/2015, including 107 universities and 217 universities of applied sciences (*Fachhochschulen*).[2] In addition, there were six pedagogical colleges, sixteen theological colleges, fifty-two colleges for arts and twenty-nine public administration colleges. Without question, the main knowledge transfer channel from these institutions to industry is the education of highly skilled labor. Figure 5.1 shows trends in numbers of students at different types of HE college. Between 1994 and 2015, the overall number of students increased from about 1.9 million to almost 2.8 million. While the share of colleges of arts, pedagogics, theology, and administration remained small at between 3 to 4 percent, the share of students at universities of applied sciences increased from 21 percent to 34 percent.

In addition to the HE colleges, Germany has several important research institutes: the Fraunhofer Association, the Helmholtz Association of German Research Centres, the Max Planck Association, the Leibniz Association, and several others with research missions that are financed either by the federal government or the Länder.

Figure 5.2 shows the distribution of R&D expenditure in Germany in 2010. According to the Federal Ministry of Education and Research (BMBF), total R&D expenditure amounted to about EUR 67 billion,

[1] Source: German Federal Statistical Office, www.destatis.de/DE/ZahlenFakten/GesellschaftStaat/BildungForschungKultur/Hochschulen/Tabellen/Hochschulen Hochschularten.html.

[2] Universities of applied sciences focus on applied aspects of higher education. They grant bachelor and master's degrees but are generally not entitled to grant doctorates.

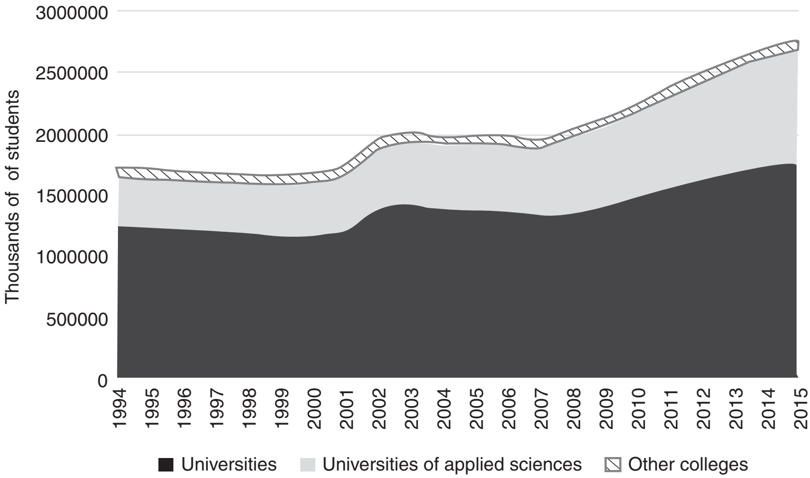

Figure 5.1 Number of students at different types of HE college in Germany
Source: Statistisches Bundesamt (2016), Fachserie 11, Reihe 4.1.

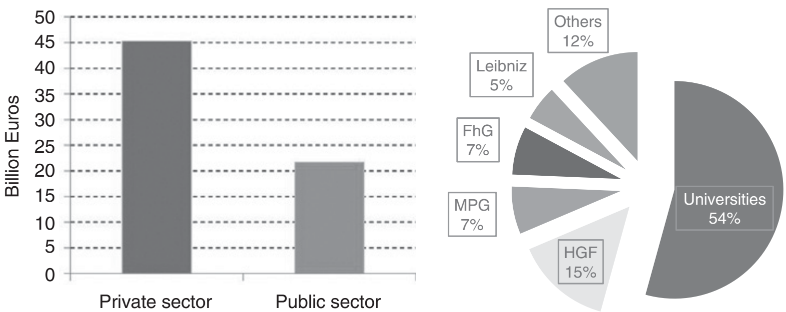

Figure 5.2 Distribution of R&D expenditure in 2010
Source: BMBF (2012)
Note: FhG is the Fraunhofer Association, HGF is the Helmholtz Association and MPG is the Max Planck Association.

with about EUR 45 billion spent by the private sector, and EUR 22 billion by the public sector. Universities and other HE colleges spent about 54 percent of that EUR 22 billion. The rest was distributed among public research institutes, with the largest share of 15 percent being spent by the Helmholtz Association, followed by the Max Planck and Fraunhofer

Associations with about 7 percent each, and the Leibniz Association with 5 percent. The other public research institutes spent about 12 percent of the total public research budget.

The Fraunhofer Association's research activities are conducted by sixty-nine institutes and research units at locations throughout Germany. It employs around 24,500 people, who work with an annual research budget totaling EUR 2.1 billion. Of this, EUR 1.9 billion is generated through contract research. More than 70 percent of its contract research revenue is derived from contracts with industry and from publicly financed research projects (Fraunhofer Association 2015).

The Helmholtz Association of German Research Centres was created in 1995 to formalize existing relationships between several independent research centers that are mainly engaged in "Big Science." It employed 38,237 people in 2015, and distributes core funding from the BMBF to its eighteen autonomous research centers. The 2015 budget amounted to EUR 4.45 billion, with roughly two-thirds coming from public sponsors (split 9:1 between federal and state authorities). The individual Helmholtz Centres attract more than 30 percent of funding themselves through contracts with public and private sector sponsors (Helmholtz Association 2016).

The Max Planck Association consists of eighty-three institutes (including five abroad) and mainly engages in basic research. As at January 2016, it had a total of 22,197 staff. The federal and state governments each provide half the institutional funding for its budget, which totaled around EUR 1.8 billion in 2016 (Max Planck Society for the Advancement of Science 2016).

The Leibniz Association is a conglomerate of research institutes that are members of the so-called Blue List – institutes that were originally founded by the Länder, but which are now regarded as being of federal importance and therefore cofinanced by the federal government. In 2015, Leibniz comprised eighty-nine institutes employing 18,476 people with a total budget of EUR 1.73 billion, of which around 21 percent came from third-party funding.[3]

Table 5.1 summarizes some key features of the major public research institutes.

5.2.1 Knowledge Transfer Prior to the 2000s

The knowledge and technology transfer (KTT) activities of German universities/HE colleges and public research institutes differ, reflecting

[3] Source www.leibniz-gemeinschaft.de/ueber-uns/organisation/leibniz-in-zahlen.html.

Table 5.1 *Selected key features of German public research institutes*

	Fraunhofer	Helmholtz	Max Planck	Leibniz
Orientation	Applied	Big Science	Basic	Diverse
Institutes	69	18	83	89
Staff	24,500	38,237	22,197	18,476
Budget	EUR 2.1 billion (EUR 1.9 billion from contract research)	EUR 4.45 billion (2/3 from public sponsors; 9:1 federal–state split)	EUR 1.8 billion (50:50 federal–state split)	EUR 1.73 billion (21 percent third-party funding)

Sources: Various annual reports of the institutions

their differing missions. Based on a survey of professors at universities and Fachhochschulen plus heads of departments at public research institutes, Czarnitzki et al. (2000) assessed the extent to which different institutions met preconditions for KTT and how much KTT they actually carried out. This analysis was further developed by Edler and Schmoch (2001), and is shown in Figure 5.3.

Information on the preconditions for KTT was derived from institutions' mission statements supplemented by their size in terms of budgets and staff as well as their thematic orientations. These preconditions were then compared to the actual extent of KTT activities, as derived from the survey responses of almost 1,000 professors and heads of department. The extent of KTT takes into account the industry affinity of each institution's research, its interaction with industry, staff mobility between the institution and industry, and research funding obtained from industry.

Institutions are localized on the "KTT activity map" roughly according to their missions. The Fraunhofer Association had the highest predisposition for KTT to industry and also achieved the highest extent of KTT. It was followed by technical universities as a distinct subgroup of universities that are well suited to KTT because they generally focus on subjects that are highly relevant to industry. The Helmholtz Association seemed to meet many preconditions for KTT but was less active in practice than the technical universities. There were then significant variations among

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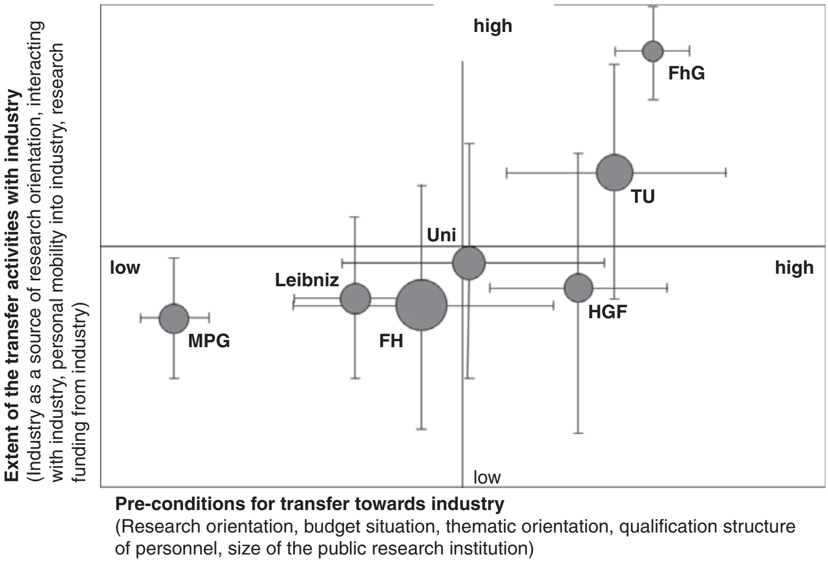

Figure 5.3 KTT missions and activities of different institutions in German public science

Note: Adapted from Rammer and Czarnitzki (2000) and Edler and Schmoch (2001). The size of the bubbles shows the extent of factors impeding KTT according to survey responses. FH is Fachhochschulen (universities of applied science), FhG is the Fraunhofer Association, HGF is the Helmholtz Association, MPG is the Max Planck Association, TU is the technical universities and Uni is other universities.

other universities and universities of applied sciences in terms of preconditions for KTT. Some faced significant barriers, such as understaffed KTOs and misaligned incentives. Of all the institutions, the Max Planck Association was least active in KTT, reflecting its basic research mission within the public science system.

5.2.2 Knowledge Transfer at a Glance

Knowledge Transfer from Universities

As the universities and Fachhochschulen are administered by the Länder, no comprehensive metrics on KTT exist centrally and we are obliged to use secondary data sources. The Munich Innovation Group (2013) published a study comparing patent applications by German universities with those by Chinese institutions, and analyzed the PATSTAT database

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of the European Patent Office, which contains data from many different national patent offices.[4] The fifteen German universities with the highest patent activity between 1990 and 2009 are shown in Table 5.2. To compare this ranking with research activity, the table also includes the

Table 5.2 *Top-ranking universities for patent applications, 1990–2009, and research*

University	Rank: patent applications[a]	Number of patent applications[a]	Rank: citations per faculty[b]	Rank: academic reputation[c]
KIT, Karlsruhe Institute of Technology[d]	1	3,780	5	12
Technische Universität Dresden	2	1,495	3	16
Albert-Ludwigs-Universität Freiburg	3	1,103	6	7
Freie Universität Berlin	4	1,038	9	4
Eberhard Karls Universität Tübingen	5	1,027	36	13
Humboldt-Universität zu Berlin	6	839	18	2
Universität Stuttgart	7	770	19	18
Universität Jena	8	769	33	28
Friedrich-Alexander-Universität Erlangen-Nürnberg	9	708	1	22

[4] For more discussion of the strengths and weaknesses of PATSTAT as a data source, see Chapter 3 in this volume.

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Table 5.2 (*cont.*)

University	Rank: patent applications[a]	Number of patent applications[a]	Rank: citations per faculty[b]	Rank: academic reputation[c]
Technical University of Munich	10	635	24	5
Ruprecht-Karls-Universität Heidelberg	11	598	16	3
Ludwig-Maximilians-Universität München	12	536	10	1
RWTH Aachen University	13	515	13	6
Georg-August-University Goettingen	14	389	27	8
Technische Universität Berlin (TU Berlin)	15	381	22	9
Leibniz Universität Hannover	n/a	n/a	2	29
Technische Universität Darmstadt	n/a	n/a	4	23
Julius-Maximilians-Universität Würzburg	n/a	n/a	7	24
University Ulm	n/a	n/a	8	27
Universität Rostock	n/a	n/a	11	43

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Table 5.2 (*cont.*)

University	Rank: patent applications[a]	Number of patent applications[a]	Rank: citations per faculty[b]	Rank: academic reputation[c]
WHU – Otto Beisheim School of Management	n/a	n/a	12	45
Ruhr-Universität Bochum	n/a	n/a	14	25
Justus-Liebig-University Giessen	n/a	n/a	15	42
Rheinische Friedrich-Wilhelms-Universität Bonn	n/a	n/a	28	11
Universität Hamburg	n/a	n/a	35	10
Universität Frankfurt am Main	n/a	n/a	37	14
University of Cologne	n/a	n/a	38	15

Notes:

a. *Source:* Munich Innovation Group (2013).

b. *Source:* QS World University Ranking 2016/2017; www.topuniversities.com/university-rankings/world-university-rankings/2016. Ranks are within Germany and are based on a citation-to-paper ratio per faculty member in order to remove size effects. The publication and citation analysis is based on the Scopus database.

c. *Source:* QS World University Ranking 2016/2017; www.topuniversities.com/university-rankings/world-university-rankings/2016. Ranks are within Germany and are based on a survey of scientists.

d. The Karlsruhe Institute of Technology is a merger between the former University of Karlsruhe and the Forschungszentrum Karlsruhe, an institute of the Helmholtz Association.

fifteen top-scoring universities in terms of research publication citations based on the Scopus database as well as the highest ranking in terms of academic reputation according to the QS World Ranking of Universities. As can be seen, top patenting correlates with top research, but not as strongly as one might expect.

Unfortunately, patent applications are almost the only indicator of KTT from universities and Fachhochschulen that can be traced systematically with moderate effort. Other indicators such as licensing, spinoff activity, joint research projects with industry, and other more informal contacts are not collected on any systematic basis. Such data could only be gleaned from the annual reports of individual institutions (and even then comprehensive data are not available) or collected through surveys.

Knowledge Transfer by Public Research Institutes

A decade after the analysis by Rammer and Czarnitzki (2000) and Edler and Schmoch (2001), a survey of public research institutes conducted in 2009 by the Centre for European Economic Research (ZEW) offered an updated perspective. The heads of different public research institutes were asked whether various tasks featured in their institute's main mission. Public research institutes are often associations of many different institutes, and so there was scope for considerable variation among replies from heads within a single umbrella public research institute. Interestingly, the heads' subjective assessment in this survey generally chimes with the earlier findings reported in Figure 5.3.

Table 5.3 shows some key results of the 2009 survey. The most emphatic replies came from the Max Planck Association and the Fraunhofer Association. As expected, Max Planck views itself as provider of basic research insights: 100 percent of its heads view basic research as one of their main tasks. This is followed by providing PhD and other education (22 percent), which can be seen as an indirect channel of knowledge transfer (not necessarily to industry), and the provision of scientific information to the public (19 percent). Note the striking gap between basic research (100 percent) and the next most important task, PhD education (22 percent) – the most pronounced unimodal orientation among all public research institutes. Active knowledge transfer is not seen as one of the institute's main tasks.

This stands in stark contrast to the Fraunhofer Association, which has traditionally focused more on applied research. Here 91 percent of heads see applied research as a main task of their institute, followed by

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Table 5.3 *Public research institute heads' assessment of their institutes' key tasks (%)*

	Total	Max Planck	Fraunhofer	Helmholtz	Leibniz	PRO (Federal)
Basic research	44	100	9	46	62	7
Applied research	57	3	91	57	48	74
Technical development	18	3	46	26	6	7
Testing, standardisation, and certification	11	0	17	6	6	26
Information and documentation	11	3	3	3	23	22
PhD education, Further education	16	22	3	34	19	7
Providing scientific infrastructure	15	6	11	37	13	15
Tech transfer to private sector	26	3	57	31	12	7
Scientific information of public	15	19	0	14	23	15
Counseling services public administration	20	3	9	17	19	78
Fulfillment of regulatory tasks	13	3	3	9	10	56

Source: ZEW – Leibniz Centre for European Economic Research 2009 PRI Survey
Notes: Figures show the percentage of heads at each public research institute judging a specific task as a goal of their institute.

knowledge transfer to industry (57 percent) and technical development (46 percent).

The Fraunhofer and Max Planck Associations take extreme positions in terms of basic versus applied research and development and active knowledge transfer. Other public research institutes have more balanced missions. For instance, the heads of the Helmholtz institutes regard basic and applied research as almost equally important (57 percent versus 46 percent). Helmholtz represents Big Science in Germany, and its heads see the provision of scientific infrastructure (which can also be accessed by non-Helmholtz researchers) as their third most important task. Direct knowledge transfer to industry is ranked fifth after providing PhD education. In sum, although Helmholtz still places more importance on basic and applied research, knowledge and technology transfer is on the agenda of its constituent institutes.

Like Helmholtz, the Leibniz Association is a hybrid between basic and applied research that does not see knowledge transfer as its main goal. Information, documentation, and the dissemination of scientific information to the public feature among its perceived missions.

The 2009 survey also provides interesting information about other public research institutes. These institutes have a strong focus on applied research (mentioned by 74 percent of their heads) and on monitoring and advising public administration (78 percent). A good example is the Robert Koch Institute, Germany's central institution for disease prevention and control, which operates under the Federal Ministry of Health and conducts research into vaccination and related fields. It has about 1,110 employees, including 450 scientists.

Another example is the German Meteorological Office (Deutscher Wetterdienst, DWD), which is attached to the Federal Ministry of Transport and Digital Infrastructure and whose principal tasks include warning against weather-related dangers and monitoring and rating the impact of climate change in Germany. The DWD runs atmospheric models on its supercomputer for precise weather forecasting as well as managing the national climate archive and one of the world's largest specialized libraries on weather and climate issues. While it does undertake climate research, its main tasks relate to information and documentation.

For more information about knowledge transfer from public research institutes to industry specifically, annual reports are a useful source. The main transfer channel is undoubtedly direct research collaboration with industry, but data on this are not readily available. Instead, Table 5.4 reports key figures on KTT based on annual reports.

Table 5.4 *KTT by leading German public research institutes at a glance*

	Patenting	Licensing	Spinoffs	Other
Fraunhofer	563 applications in 2014, 506 in 2013	Not available	Not available	EUR 641 million revenue from projects with industry in 2015
Max Planck	131 applications in 2014, 127 in 2013	80 exploitation agreements in 2014 generating revenues of EUR 23.5 million; 93 agreements in 2013 and revenues of EUR 22.5 million	117 spinoffs since 1990, 83 of them actively managed by Max-Planck Innovation; c.3,000 jobs created as of 2014	c.2,000 collaborative projects with industry per year generating annual revenues of c. EUR 158 million in 2014
Helmholtz	c.400 per year	Revenues of EUR 20 million in 2012 and 2013, and EUR 11.7 million in 2015	118 spinoffs between 2005 and 2014, 21 in 2015	c.EUR 150 million per year revenue from industry partnerships
Leibniz	2,605 between 1990 and 2009	n/a	n/a	Third-party funding of c.EUR 363 million in 2014 (22.1 percent of all funding)

Sources: All data derived from annual reports of the public research institutes except for patent data for the Leibniz Association, which comes from Munich Innovation Group (2013)

As expected, the Fraunhofer Association is very active in patenting due to the applied nature of its research, and secured EUR 641 million revenue from projects with industry in 2015. The Helmholtz Association is also very active in patenting – perhaps more than one might expect given its focus on Big Science – but earns much less than Fraunhofer from industry partnerships. The various Max Planck institutes patented only 131 inventions between them in 2014, in line with their basic research focus.

According to the Munich Innovation Group (2013), the Leibniz Association patented 2,605 inventions between 1990 and 2009, giving a similar annual total to that of Max Planck. Third-party funding amounted to about EUR 363 million, but it is unclear how much of this came from industry.

For Max Planck and Helmholtz, licensing income and spinoff numbers are also available, but these are difficult to compare across institutions. Max Planck reports that it has created117 spinoff companies since 1990, which in turn created about 3,000 jobs as of 2014, but it is unclear whether those jobs still existed in 2014, or whether the figure refers to employment in terms of "person-years" since 1990. Helmholtz outperformed Max Planck by creating 118 spinoffs between 2005 and 2014, but reported only EUR 20 million of research revenues compared with Max Planck's EUR 23.5 million. Furthermore, Helmholtz's revenues trended downward during the period of the study.

In summary, German universities and Fachhochschulen are not the only relevant institutions for knowledge and technology transfer from science to industry; public research institutes without teaching obligations play a crucial role in the public science landscape. Knowledge transfer seems to be actively supported by most universities and public research institutes.

5.2.3 Leading Users of Commercially Valuable Knowledge

In the Mannheim Innovation Panel (MIP), which constitutes the German part of the pan-European Community Innovation Surveys (CIS), firms are regularly asked about their innovation activities. The survey takes a representative sample of German manufacturers and selected services and its results can thus be extrapolated to all German firms in these sectors.

Among many other questions, firms are asked to report on their partners in innovation projects. As well as lead customers, suppliers, firms from the same industry and consultants, they also indicate whether they collaborate with universities, including universities of applied sciences, and public research institutes.

As can be seen in Table 5.5, of firms in the R&D service sector, 66 percent collaborate with universities and 40 percent with other public research organizations. This is followed by the pharmaceutical sector, where 54 percent of firms report collaboration with universities and 30 percent with public research institutes. Other sectors that collaborate extensively with public science include ICT equipment, vehicles, machinery, chemicals, metal, and the ICT industry.

Interestingly, universities are generally reported more frequently than public research institutes. In part, this may simply be because they outnumber public research institutes, but it also shows that universities are frequently involved in knowledge transfer activities through joint research. These activities may well exceed the patenting of university inventions by the university KTOs themselves in terms of both frequency and importance.

For public research institutes, there is also survey data on the users of their research results. In the 2009 ZEW public research institutes and universities survey, heads of institutes were asked to report on their most important user groups. Interestingly, their most important user group was universities, mentioned by 52 percent of respondents, followed by other public research institutes on 37 percent. Small and medium-sized firms and large firms were each mentioned by around one-third of respondents (see Table 5.6).

Once again, the biggest differences between public research institutes occur between Max Planck and Fraunhofer. While Max Planck heads almost exclusively report other scientific institutions as their main user group (universities and public research institutes with 84 percent and 40 percent, respectively), the Fraunhofer institutes focus unambiguously on industry, with large firms mentioned by 83 percent of heads and SMEs by 91 percent.

For the other institutions, the picture is again more mixed but public science as user dominates, except for other federal public research institutes that do not belong to one of the four major associations, where public administration is evidently the most important "client."

5.2.4 Changes in the German Knowledge Transfer System

In the period 1998–9, the BMBF commissioned a study of knowledge and technology transfer in Germany, the results of which were published (Schmoch et al. 2000). In response to the study, the BMBF launched

Table 5.5 *Leading collaboration partners by sector, 2008–10*

	Collaborations with:			
	Universities and Fachhochschulen		Other public research organizations	
	Rank	Share of innovators* (in percent)	Rank	Share of innovators* (in percent)
R&D services	1	66	1	40
Pharmaceuticals	2	54	2	30
ICT equipment	3	47	3	29
Vehicles	4	43	4	26
Machinery	5	38	6	19
Chemicals	6	33	5	25
Metal	7	32	7	15
ICT services	8	32	8	14

Source: Authors' calculations based on the Mannheim Innovation Panel (2011)

* Share of innovating firms reporting collaboration within the context of innovation projects.

Table 5.6 *Main users of public research institute research, as identified by public research institute heads*

	Total	Max Planck	Fraunhofer	Helmholtz	Leibniz	PROs (Fed.)	Others
Universities	52	84	11	54	77	33	40
PRIs	37	40	3	34	64	33	33
Public administration	27	0	9	23	31	96	19
Large firms	30	0	83	37	15	11	31
SMEs	33	0	91	17	19	7	54
Industry associations	7	0	14	3	4	7	10
Broader public	12	3	0	9	15	22	19

Source: ZEW 2009 public research institute and universities survey

Notes: Figures show the percentage of respondent public research institute heads who reported a specific user group as using their institution's research.

a campaign called "Knowledge Creates Markets" in 2001 with four major objectives: (i) a valorization campaign to increase patenting by public research organizations; (ii) a spinoff campaign to encourage them to found companies; (iii) a collaboration campaign to foster bilateral research agreements between public research organizations and companies; and (iv) a competence campaign to increase awareness of the potential usefulness of public science among companies. In total, the four campaigns included twenty-six sub-schemes.

Major subsequent changes with respect to KTT in Germany included the abolition of professor's privilege and the establishment of regional "patent valorization agencies" (PVAs) intended to support university KTOs and researchers in commercializing their discoveries.

The Abolition of Professor's Privilege

The abolition of professor's privilege was a major change both legally and culturally. Under Clause 42 of the German employee invention law, university researchers owned inventions made in the course of their work. This was a unique legal privilege – ownership of all other inventions created in the course of employment are vested in the employer – and reflected Article 5 of the German constitution, which protects the freedom of science and research.

Under the new law, introduced in 2000, German university researchers are now required to scrutinize their research findings and report any inventions to the university – unless they decide to keep their inventions secret by not publishing or patenting. The university has four months to consider patenting any inventions so submitted. If it does not claim the invention, rights to patent and commercialize it revert to the researcher. If it does claim it, the inventor is entitled to at least 30 percent of revenues from successful commercialization, but nothing otherwise. Furthermore, the university handles the patenting process and pays all related expenses such as processing fees, translation costs, and legal expenses. University researchers retain the right to disclose the invention through publication two months after submitting it to the university. Prior contractual agreements with third parties also remained valid during a prescribed transition period.[5]

A handful of studies have examined the effects of abolishing professor's privilege on patenting rates and ownership patterns in Germany. Schmoch (2007) found that the number of university-owned patents

[5] Contracts made before July 18, 2001 were treated under the old law until February 2003 (Gesetz über Arbeitnehmererfindungen, § 43 ArbnErfG).

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increased. Based on inventor lists, his data also suggest that the new law changed the propensity to invent among academics, discouraging those who had previously filed their own patents while encouraging non-patenters. In a follow-up study, Cuntz et al. (2012) showed that the share of university-owned inventions increased after 2002 while the share of individually or industry-owned university inventions decreased. Von Proff et al. (2012) found that the policy change did not increase university-invented patents, but that ownership merely shifted from individual- and firm-owned patents to universities.

Czarnitzki et al. (2015c) analyzed the effects of the change in law through a more rigorous micro-econometric study using the difference-in-difference methodology, comparing university-based patenting to the patenting activity of a control group of inventors before and after the change.

In essence, Czarnitzki et al. (2015c) argue that university patenting cannot be compared to general patenting activity in Germany, which is dominated by inventors employed in firms. As the reward systems in firms and public science are very different, they instead aim to compare patenting by university researchers with patenting by researchers employed by public research institutes.

Choosing a good control group of inventors is clearly crucial to evaluate the impact of policy changes. Figure 5.4 shows patenting activity in Germany, with the dotted line at the top showing the overall trend.

The underlying data are applications filed with the German Patent and Trademark Office (DPMA) and the European Patent Office (EPO) between 1978 and 2008 involving at least one German inventor. Data were collected from PATSTAT. Treating 1995 as the baseline (100 percent), patenting grew until the year 2000 and reached about 145 percent, then fell to about 140 percent in 2002, and then grew again to reach 160 percent in 2008. However, academic patenting developed very differently. Patent filings based on university and public research institute inventions both grew from 100 percent in 1995 to roughly 110 percent in 1998, but then both fell, to 70 percent and 80 percent respectively, in 2002 when the law changed. This pattern was found by prior researchers (Schmoch 2007; Cuntz et al. 2012; Von Proff et al. 2012). Analysts have speculated about the reasons for the decrease: suggestions include an increasing emphasis on publication in academic performance evaluations, decreased entry into academic jobs, the end of the New Economy boom and legal uncertainty surrounding patenting in the field of biotechnology (Schmoch 2007: 5–8; Cuntz et al. 2012: 21–2).

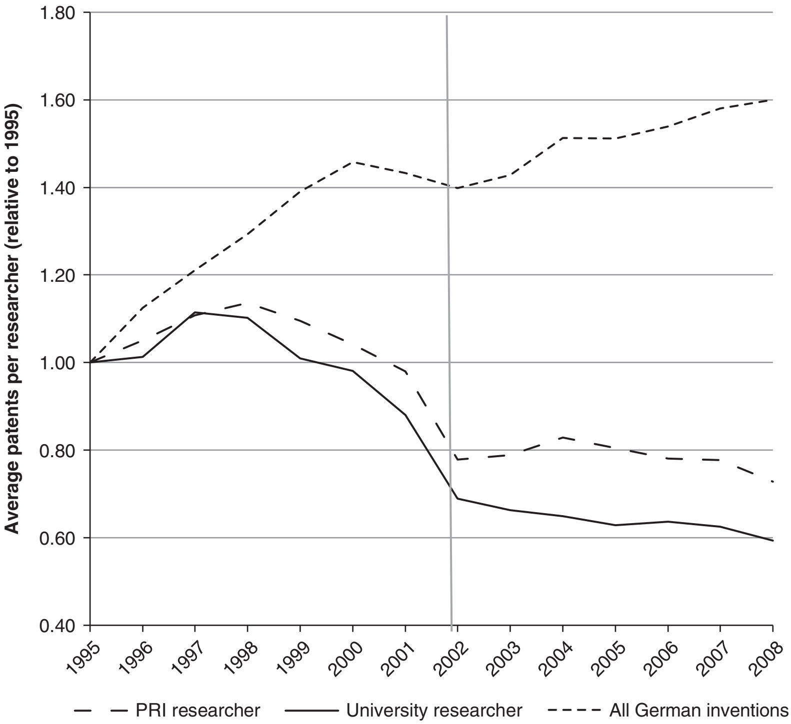

Figure 5.4 Patenting in Germany before and after the abolition of professor's privilege
Source: Czarnitzki et al. (2015c)

Patenting by public research institutes did at first recover slightly after the change in law, but university patenting continued to decline.

For more rigorous analysis, Czarnitzki et al. (2015c) collected a panel of patent and publication data at the level of individual inventors at universities and public research institutes. The panel methodology allows one to control for individuals' ability to commercialize research, annual macroeconomic shocks, and each researcher's career age and publication record. Publications may serve as a control variable, reflecting potentially patentable new knowledge.

Figure 5.5 shows trends for the study group (university researchers) and the control group (public research institute researchers) as "within" demeaned average time series, that is, average patenting activity for each person over the whole panel time period is subtracted from their actual

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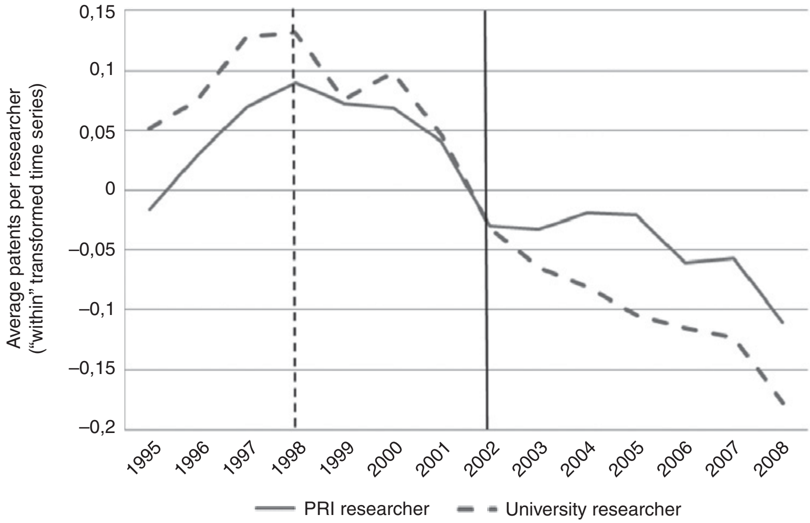

Figure 5.5 Trends in German patenting for university and public research institute researchers ("within" transformed), 1995–2008
Source: Czarnitzki et al. (2015c)
Note: The lines show "within" demeaned, averaged values for university and public research institute researchers. The 2002 vertical solid line marks the date of the actual policy change. The 1998 dashed vertical line shows the date on which the first public discussion took place, according to Internet searches.

observed patenting. This wipes out differences in levels of the time series which might be due to individuals' specific ability to patent. Here, we are more interested in changes over time rather than different levels of patenting activity among individuals. The figure shows that patenting by researchers at universities and public research institutes followed a similar trend before the law changed and diverged slightly between 1998 and 2001, when abolition of professor's privilege was under discussion, but that they diverged strongly after abolition. While public research institute patenting first stabilized in 2005, university patenting dropped steadily until 2008.

Having run micro-econometric fixed-effect panel regressions that also control for researchers' career ages and publication records, Czarnitzki et al. (2015c) conclude that the law change caused patenting by university researchers to fall by about 17 percent. Thus, the policy failed in its goal of

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Table 5.7 *University researchers' patent activity by applicant type, 1995–2008*

	Before 2002		After 2002	
Applicant type	Average patents per inventor per year	Relative frequency (in percent)	Average patents per inventor per year	Relative frequency (in percent)
Industry	0.45	74	0.23	62
Individual	0.14	23	0.04	11
University	0.02	3	0.10	27
Sum	0.61	100	0.37	100
Total*	0.58		0.34	

Source: Czarnitzki et al. (2016)

* *Note:* In total, the average number of patent applications per identified university inventor per year amounted to 0.58. However, a few patents are co-assigned to multiple types, e.g., a firm and a university file a joint patent application. These are counted for each type, so the total by type amount to 0.61 before 2002 instead of 0.58.

increasing patenting. The authors argue that policymakers misperceived the incentives of university researchers. It was assumed that university researchers were mainly interested in publishing their work in academic journals and most were not interested in commercializing their research results. Instead, however, researchers who were interested in commercialization before the law changed maintained viable networks of industry contacts and often patented in collaboration with companies. These networks were disrupted by the law change, and university researchers instead had to involve university KTOs in negotiations about contract research, IP, and related collaborations.

Czarnitzki et al. (2015c) argue that the cost-and-benefit schedules for university inventors have shifted because of the change in IP ownership. On the one hand, KTOs now cover the cost of patent applications and associated fees, and are also supposed to look for industry partners for commercialization. Prior to the law change, researchers had to invest effort and their own money to realize commercial opportunities. On the other hand, researchers have lost the opportunity to appropriate all revenues from their patenting activity. Prior to the law change, they could theoretically enjoy 100 percent of potential revenues; now, they obtain a 30 percent royalty on all revenues, and the universities own the other 70 percent. In addition, bargaining has become more complex as now, in addition to the researchers, the university's KTO is involved in negotiations with the firm. The empirical results of Czarnitzki et al. (2015c) suggest that the negative incentives (forgone private benefits of commercialization) outweigh the positive incentives (lower private cost of commercialization).

Czarnitzki et al. (2016) separates patenting by university researchers by applicant type (see Table 5.7). Before 2002, total patenting per university inventor per year amounted to about 0.58 patent applications per year. After the law changed, this total dropped to 0.34. However, the decline causally related to the law change is about 17 percent of the initial value of 0.58 only (according to the results from Czarnitzki et al. 2015c). More interestingly, Table 5.7 shows that a large chunk of the decline in patenting is due to a fall in patents where university researchers appear as inventors on corporate patent applications. These patents related to industry have declined by around 50 percent, from 0.45 before the law change to 0.23.

In addition, patents may be filed by individuals, typically university inventors themselves, or by the university. Before 2002, an average of 0.14 patents were filed individually by each university inventor, and 0.02 by each university. As can be seen in Table 5.7, these numbers basically switched around, in line with the change in the law on IP ownership. After 2002, patents filed by individuals fell to 0.04 while university-filed patents increased from close to zero to 0.10, amounting to 27 percent of total patent applications based on university inventions. Applications by individual researchers amount to just 11 percent. These are inventions where the KTO was not interested in claiming ownership or the university researcher did not report the invention to the university. Patent applications with industry are still the largest share with 62 percent. Note that universities are not required to claim ownership of the IP. They may well contract to transfer ownership to firms. The key change is that prior to 2002, the researcher was able to negotiate directly with industry, while now it is the university KTO that does so.

Patents filed along with industry applicants dropped dramatically from 0.45 to 0.23 per inventor per year. These most likely stem from direct research collaborations or contract research between industry and university researchers, strongly suggesting that the abolition of professor's privilege reduced actual knowledge and technology transfer. The loss of private income opportunities seems to have outweighed the possible benefits in terms of the reduced cost of commercialization for researchers.

The Introduction of Patent Valorization Agencies

As part of the Knowledge Creates Markets campaign, the BMBF established patent valorization agencies (PVAs). By 2012, twenty-nine PVAs had been created, with at least one in each state (Cuntz et al. 2012). Their primary mission is to help universities commercialize their research by providing advice on patenting, licensing and forming spinoffs. They also help to find business partners and licensees.

The main public funding for the PVAs is provided through the SIGNO program of the Federal German Ministry of Economics (BMWi). Funding is assigned to universities, which then use it to request services from the PVAs. The SIGNO budget amounted to EUR 29 million between 2001 and 2003, EUR 38 million between 2004 and 2007, and EUR 29 million between 2008 and 2010. Universities must top this up through co-payments. Cuntz et al. (2012) calculated that the PVAs' annual budgets totaled between EUR 9 and EUR 10 million in the period 2002–9.

Cuntz et al. (2012) also calculated that the revenues generated by the PVAs did not cover their cost: between 2002 and 2009, they never exceeded EUR 6 million.

It may be, however, that although the PVAs operate at a loss, their KTT activities bring indirect benefits. For instance, the foundation of more spinoff companies would not necessarily be reflected in higher PVA revenues. Researchers may be more likely to found their own companies, possibly in collaboration with a university KTO, after the establishment of PVAs and the abolition of professor's privilege, as KTOs may now be more actively pushing commercialization through spinoffs and this process may be strengthened by the presence of the PVAs. To test this hypothesis, Czarnitzki et al. (2016) investigated whether more or fewer spinoff companies have been founded since the abolition of professor's privilege and the establishment of PVAs. They collected data by searching for identified academic inventors among the population of firm founders in Germany. The Creditreform database (the German part of Bureau van Dijk's Orbis database) includes the names of all firm founders along with information on the foundation year, shareholdings, basic firm-level accounting, and supplemental data. Importantly, this captures not only spinoffs established by university or public research institute KTOs, but also those launched by researchers independently.

Table 5.8 summarizes their findings. Before 2002, university researchers were involved in about 46 startups per year and this number reduced to about 43 per year. The annual probability of a researcher founding a company remained constant at 4 percent. For public research institute researchers, the number of companies founded was lower and constant over time, with 29 spinoffs per year – 1 percent per researcher per year.

Annual within-demeaned spinoff probabilities at the researcher level are shown in Figure 5.6. As can be seen, while average annual spinoff probabilities fluctuate, they remain broadly constant over time and are unaffected by the law change. This is in line with micro-econometric findings by Czarnitzki et al. (2016). Using panel fixed-effects estimators in a difference-in-difference setup, they found no direct effect of the law change on university spinoffs. In summary, it seems that university KTOs and PVAs have not successfully pushed spinoff creation as the prime channel for commercializing academic inventions.

Other Major Funding Schemes

A major program involving KTT goals was the German University Excellence Initiative (www.dfg.de/en/research_funding/programmes/excellence_initiative/index.html). This was intended to promote science and humanities to enhance Germany's international competitiveness and

Table 5.8 *Academic entrepreneurship before and after the 2002 policy reform (annual mean values), 1995–2008*

		Startups founded per year	Startups founded per year per inventor
University researcher	Before 2002	46.43	0.04
	After 2002	42.57	0.04
PRI researcher	Before 2002	29.43	0.01
	After 2002	28.71	0.01

Source: Czarnitzki et al. (2016)

Note: The sample included 1,946 patenting university researchers and 4,551 public research institute researchers.

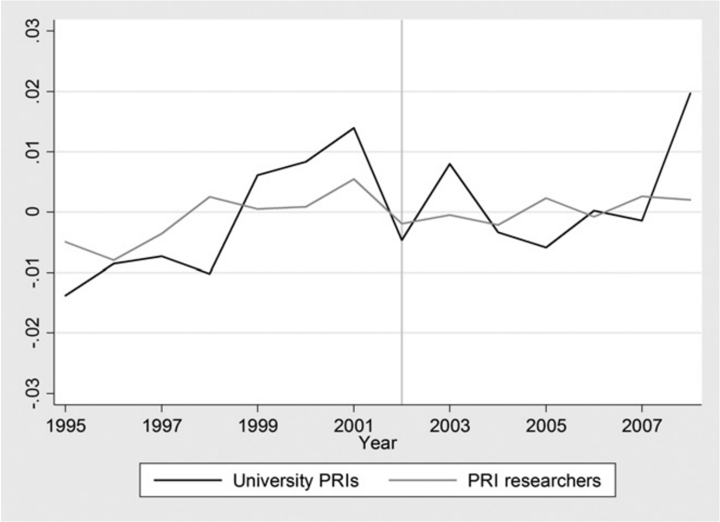

Figure 5.6 Average trends of spinoff activity (within demeaned)
Note: The vertical line in 2002 denotes the abolition of professor's privilege.
Source: Czarnitzki et al. (2016)

increase the visibility of top-level universities. It ran from 2005 to 2017 and comprised three funding lines:

- the establishment of graduate schools at universities to promote young researchers;
- funding "clusters of excellence" to promote top-level research; and
- institutional strategies to strengthen the institution "university" and its research setting as a whole.

In total, EUR 4.6 billion of funding was approved through the three funding lines, EUR 1.9 billion in the program's first phase (2006–12) and EUR 2.7 billion in its second phase (2012–17). While the program was not directly targeted at knowledge transfer, it helped universities strengthen their staffing and equipment, and some of these additional resources may have been used for business-relevant research and knowledge transfer.

Another relevant policy is the *Spitzencluster* ("top cluster") initiative (www.spitzencluster.de), in which universities, public research institutes, and firms team up to boost their research and innovation activities. Fifteen clusters were selected in three different program rounds, and each could obtain funding up to EUR 40 million over a five-year period.

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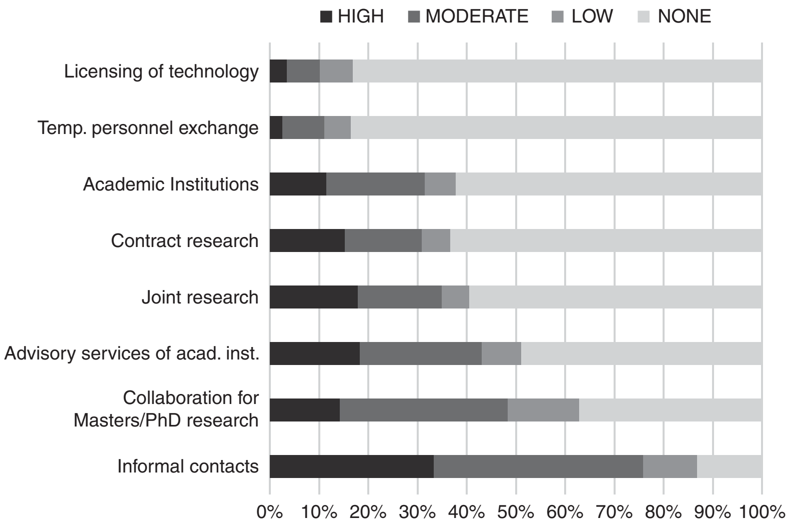

Figure 5.7 The firms' perspective on KTT channels
Source: ZEW Mannheim Innovation Panel (Survey 2003), authors' calculations

A very recent program launched in 2016 and directly targeted at KTT is the Innovative Hochschule scheme (www.bmbf.de/de/innovative-hochschule-2866.html), which targets Fachhochschulen and small and medium-sized firms and has a budget of up to EUR 550 million to be disbursed in two five-year rounds until 2027. The main applicants are universities but firms can also be supported within project consortia. The goal is to strengthen universities' KTT activities, increase links within regional economies, and promote innovative forms of collaboration with business.

The EXIST program (www.exist.de) has supported academic entrepreneurship since 1998. It has three main pillars: (i) the "founder's fellowship" supports potential firm founders in academia to develop their business idea and create a business plan; (ii) the "research transfer" is intended to help develop applied research projects with commercial potential; and (iii) the "foundation culture" aims to help universities strengthen their infrastructure and enhance researchers' awareness of KTT.

5.3 Common Knowledge Transfer Channels

To identify important channels of knowledge transfer in Germany and see how they have changed over time, we can use two surveys by ZEW.

The first survey was carried out in the year 2000 and included 856 responses from university professors and public research institute department heads (Czarnitzki et al. 2000).

Among many other questions, respondents evaluated the importance of different knowledge transfer channels on a four-item Likert scale (0 = no importance, 3 = high importance). Table 5.9 shows the average values per type of institution, including general universities, technical universities, and universities of applied sciences. In the period 1997–9, general universities regarded publication in academic journals as the main knowledge transfer channel. Technical universities rated joint research projects with firms as important as publication and also emphasized the importance of contract research, collaborations on master's and PhD theses, and contacts from researchers' former occupation in the corporate sector. For universities of applied sciences, thesis collaboration was the most important channel, followed by former work contacts, and joint research projects, all of which ranked above academic publication.

Surprisingly, staff mobility was not rated as a major transfer channel for any type of university, but it was expected to gain importance in the future. All types of university also expected firm formation by academic researchers to become more important along with other KTT measures such as seminars and lectures for firms.

Overall, university respondents expected almost all KTT channels to become more important, indicating the growing importance of KTT generally as the third mission of the university system.

Responses from public research institutes reflected each institution's mission. Generally, respondents from the Fraunhofer institutes focused on direct knowledge transfer channels such as joint research projects, contract research, and presentations to firms. Respondents from Max Planck and Helmholtz tended to emphasize basic research and academic publication. For the Leibniz institutes, the results were more mixed but generally closer to Fraunhofer than to the other public research institutes.

In 2008, the ZEW conducted another survey among around 1,500 researchers (Grimpe et al. 2009). Although the questions in that survey are not fully comparable to the ones in Czarnitzki et al. (2000), some insights can be gained.

Table 5.9 *Importance of main knowledge transfer channels, by universities and public research institutes, 1997–9*

	UNI	TU	UAS	MPG	HGF	FhG	WGL
Publication in academic journals	2.2	2.1	1.3	2.8	2.2	2.0	2.4
	(–0.0)	(+0.1)	(+0.2)	(+0.1)	(+0.0)	(+0.1)	(+0.1)
Joint research projects with firms	1.6	2.1	1.7	1.6	1.7	2.9	2.2
	(+0.3)	(+0.2)	(+0.4)	(+0.4)	(+0.5)	(+0.1)	(+0.1)
Presentations to firms or related organizations	1.4	1.6	1.5	1.5	1.5	2.6	1.7
	(+0.2)	(+0.1)	(+0.3)	(+0.2)	(+0.3)	(+0.1)	(+0.3)
Publication of research results in the press	1.2	1.4	1.2	2.0	1.6	2.2	1.7
(newspapers, magazines)	(+0.1)	(+0.2)	(+0.2)	(+0.1)	(+0.1)	(+0.2)	(+0.2)
Contract research for firms	1.2	1.8	1.4	0.3	1.2	2.9	1.3
	(+0.3)	(+0.2)	(+0.5)	(+0.2)	(+0.5)	(0.0)	(+0.3)

Master's and PhD theses in collaboration with	1.3	1.8	2.5	0.9	0.9	1.6	1.0
firms	(+0.3)	(+0.2)	(+0.0)	(+0.2)	(+0.4)	(+0.2)	(+0.3)
Personnel mobility of researchers between research organizations and firms	1.4	1.6	0.9	1.6	1.3	2.0	1.2
	(+0.4)	(+0.4)	(+0.4)	(+0.3)	(+0.4)	(+0.2)	(+0.5)
Contacts from academics' former occupation	1.0	1.7	2.1	1.2	1.0	2.0	0.9
in the corporate sector	(+0.1)	(+0.0)	(+0.0)	(0.0)	(+0.1)	(+0.2)	(+0.3)
Joint publications and patent applications	0.8	1.0	0.8	1.1	1.0	1.9	1.3
with firms	(+0.4)	(+0.2)	(+0.4)	(+0.5)	(+0.5)	(+0.2)	(+0.3)
Seminars and lectures for firms	0.7	0.9	1.3	0.7	0.7	1.4	0.7
	(+0.4)	(+0.4)	(+0.5)	(+0.1)	(+0.3)	(+0.4)	(+0.3)

Table 5.9 (*cont.*)

	UNI	TU	UAS	MPG	HGF	FhG	WGL
Firm formation by academic employees	0.6	0.8	0.6	0.9	0.7	1.0	0.8
	(+0.5)	(+0.5)	(+0.5)	(+0.6)	(+0.6)	(+1.0)	(+0.6)

Source: Czarnitzki and Rammer (2000)

Notes: The numbers are averages of the four response scores (0 = no importance, 1 = minor importance, 2 = moderate importance, 3 = high importance) for the importance of the different channels in the years 1997–9. The expected change in importance of each channel in the future is given in the parentheses (calculated as positive or negative deviation from the mean of its current importance).Types of institutions: UNI = general universities, TU = technical universities, UAS = universities of applied sciences (Fachhochschule), MPG = Max Planck Association, HGF = Helmholtz Association, FhG = Fraunhofer Association, WGL = Leibniz Association (Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz).

Table 5.10 *External funding and channels of commercialization as reported by researchers in 2008*

	Uni	Fraunhofer	Max Planck	Helmholtz	Leibniz
External funding:					
Third-party funding	88	88	73	79	81
Industry funding	37	80	15	24	26
Channels of knowledge transfer:					
Joint commercialization of technology	43	87	21	39	44
Joint publications	24	43	15	14	20
Consulting	20	26	11	8	8
Company formation	20	18	12	10	9
Companies based on research results	12	16	8	7	6

Source: ZEW survey of scientists 2008, authors' calculations

First, most academic researchers reported having used some external funding (see Table 5.10). At universities and Fraunhofer research units, 88 percent of respondents said they had sourced external funding, but whereas 80 percent of the Fraunhofer researchers said they had received funding from industry, only 37 percent of university researchers obtained industry funds. Max Planck, Helmholtz, and Leibniz researchers received third-party funding less frequently than those at universities and Fraunhofer, but the rates of receipt were still high: 81 percent of researchers at Leibniz, 79 percent at Helmholtz, and 73 percent of Max Plank researchers said they had benefited from external funds. However, only 26 percent of researchers at Leibniz, 24 percent at Helmholtz, and 15 percent at Max Planck reported having received funding from industry.

As regards knowledge transfer channels, 87 percent of Fraunhofer researchers said they had been involved in joint research and joint commercialization of technology with industry – far higher than the corresponding numbers of researchers at Leibniz (44 percent), universities (43 percent), Helmholtz (39 percent), and Max Planck

(21 percent). Joint publications were generally the second most important channel. Private consulting activities and company formation were mentioned much less frequently. Interestingly, university researchers were more likely than other respondents to have been involved in founding an enterprise (20 percent), followed by those from Fraunhofer (18 percent). It is noteworthy, however, that in 40 percent of cases, university researchers' startups were not based on research results: while 20 percent reported involvement in establishing a firm, only 12 percent said it was based on research results. At Fraunhofer, 16 percent of respondents reported being involved in a startup based on research results. As expected, firm formation was less frequent among researchers at the other respondent public research institutes.

To investigate KTT channels at the firm level, we can use the Mannheim Innovation Panel Survey from 2003. Companies were asked to evaluate their contacts with research institutions according to their importance. Around 2,500 firms reported active contacts with public science between 2000 and 2002. The respondents were asked to rank every KTT channel according to its importance for the firm's access to knowhow on a scale between 0 and 3 (no to high importance).

Interestingly, informal contacts were the most important. More than 70 percent of firms with any active contact with science rated these as either highly or moderately important. This was followed by collaborations on master's and PhD theses, which almost 50 percent of firms ranked as highly or moderately important. Advisory services from academic institutions were highly or moderately important to 43 percent. Other formal channels such as joint research, contract research, training of employees in academic institutions, and temporary exchange of personnel as well as technology licensing played a less important role for most firms.

5.4 Economic Literature on Knowledge Transfer in Germany

The picture of KTT in Germany given above can be supplemented through a discussion of the scholarly literature. Here, we are particularly interested in two issues: the limits to and opportunity costs of KTT from science to industry, and its benefits downstream in the manufacturing and service sectors.

5.4.1 *Limits to and Opportunity Cost of KTT*

Czarnitzki et al. (2007, 2009a) studied the growing importance of universities' unpublished technology-relevant research and cooperation with industry. As more and more scientific researchers became active in commercializing their discoveries, policymakers and academics debated whether patenting as a channel of entrepreneurial activity might significantly reduce scientific output in the economy, with potentially detrimental implications for long-term growth, competitiveness, and employment. Productivity in science can be measured in terms of the publication output and research quality of scientists engaging in commercialization. Czarnitzki et al. combined bibliometric and technometric indicators and econometric techniques to investigate the correlation between patenting and publication output and quality for a large data set of academics active in several research fields in Germany. Their 2007 study found no overall negative correlation between patenting and the scientific output of the academics in their sample, but more detailed analysis revealed heterogeneity in patenting behavior. Whereas some patent applications might result from purely intrinsically motivated research, others were the output of specially funded contract research, especially for industry. Czarnitzki et al. (2009a) classified academics' patent applications into corporate patents and academic patents using applicant data, distinguishing between patents where one or more academics featured as an inventor but the patent was filed by a company and those filed by another applicant (e.g., the academic themselves or a university or public research institute). Factoring this distinction into their multiple regression models, they found that academic-filed patents did not harm academics' scientific output, but company-owned patents *were* associated with (subsequent) lower publication output and also lower publication quality (as measured through subsequent citations by other academic papers). Czarnitzki et al. interpreted this as evidence that the researchers were likely to have engaged in company-relevant research for commercialization/knowledge transfer purposes and that such research could distract them from their own, original academic research.

If one accepts that company-relevant research is likely to be of a more applied nature than normal university research then intensified knowledge transfer efforts by universities may indeed partly crowd out the freely accessible knowledge produced in science in terms of (high-quality) academic publications, potentially harming technological progress and economic development in the long run.

The opportunity cost of knowledge transfer has also been documented. In general, academic patents are more basic than corporate patents, and patents by academic inventors filed along with corporations feature inventions that are based on more applied research than those academic-invention patents owned by universities, public research institutes, or academics personally (Czarnitzki et al. 2009b, 2012). Czarnitzki et al. (2011) revealed a steady decline in the quality of academic patents. They investigated forward citations received by patent applications – a measure often employed as capturing the social value of an invention, as forward citations approximate how many subsequent inventions build on the patented technology. Czarnitzki et al. compared the forward citations received for patents by German university academics with a randomly chosen control group of patents filed by corporations in the same application year and technology field. They found that in the early 1980s, the average academic patent received significantly more forward citations than the control group of corporate patents, and they took this to indicate that academic patents were more fundamental and basic, and therefore more relevant to subsequent technological progress, than corporate patents. But as efforts to foster KTT from universities to industry grew in subsequent decades, differences between the quality or social value of academic and corporate patents, as measured by forward citations, diminished. By the beginning of the 2000s, there was no longer any statistically significant difference between forward citations of academic and corporate patents. This suggests that the move toward commercialization in academia has had a negative impact on the average social value of academic activities such as patenting. The boundary between not-for-profit academic and for-profit business R&D has become blurred.

Further studies have examined the impact of private industry funding of scientific activities on the publication of academic research results and the sharing of research materials. Czarnitzki et al. (2015a) showed that increased industry funding in Germany had hindered the dissemination of research in public science through disclosure restrictions. Arguing that the viability of modern open science norms and practices depends on public disclosure of new knowledge, methods, and materials, they sought to examine the relationship between industry sponsorship and restrictions on disclosure using individual-level data on German academic researchers. Their evidence, which controls for self-selection into extramural sponsorship, strongly supports the proposition that industry sponsorship jeopardizes the public disclosure of academic research. Academic scientists who adopt industry sponsorship are subject to more stringent contract terms that restrict the disclosure of academic research results through delay and secrecy. Controlling for scientist selection, the results show that the likelihood of such restrictions more than doubles with industry sponsorship, because firms expect proprietary benefits from their sponsorship relationships and realizing these benefits often requires disclosure restrictions that academic researchers would not otherwise impose.

These results are in line with those of Czarnitzki et al. (2015b) on access and sharing of research inputs among public scientists. The authors found that scientists who received industry funding were twice as likely to deny requests for research inputs as those who did not. Receiving external funding in general did not affect denying others access, but scientists who received external funding of any kind – from industry or elsewhere – were 50 percent more likely to be denied access to research materials by others.

In summary, active knowledge transfer does not come without opportunity cost. There is mounting evidence that the research output of public scientists is affected by their engagement in active knowledge transfer. Some may move toward more applied research, with potentially negative long-run impacts on the basic science that underpins future progress. In other cases, the dissemination of new academic knowledge may be directly impeded through disclosure restrictions imposed by private industry partners or sponsors.

5.4.2 Benefits to Business of Knowledge Transfer

While knowledge transfer can clearly have some negative impacts on the academic side, there are obvious potential benefits too. First and foremost, knowledge transfer may include private research sponsorship that enhances academic research capacities, allowing more doctoral students to be educated and so on. And even in the absence of major budget increases for public science, KTT may bring societal benefits.

The most extreme form of academic commercialization is academics' involvement in spinoff companies. In such cases, academic research is deemed valuable enough to warrant forming a company, transferring technology to the private sector and potentially adding social value by creating jobs and generating taxable revenues. Czarnitzki et al. (2014) investigated how far German academic startups grew in their first few years. They collected representative sample data from German firm foundation cohorts between 1996 and 2000 in knowledge-intensive and high-tech sectors. More than 57,000 new ventures were contacted by means of computer-aided telephone interviews, and about 20,000 interviews conducted. In their empirical analysis, Czarnitzki et al. estimated a model of company growth. They identified academic entrepreneurs among the sample of newly founded firms, and controlled for "firm survivor bias" by applying a sample selection model.[6] They found that academic spinoffs grew by around 3 percent more per year on average than other startups.

In a companion paper based on similar data, Toole et al. (2015) examined how university research alliances and other cooperative links with universities contribute to startup employment growth. They argued that "scientific absorptive capacity" at the startup is critical to reap the benefits from university research alliances, but not necessarily for other university connections. They estimated the aggregate employment contribution of startup firms and attributed those employment gains to university research alliances and other university connections. They found significant contributions to employment growth from university research alliances and other university connections, but also found that scientific absorptive capacity was critical for university research alliances. Only 7 percent of startups maintained a university research alliance, but 3.4 percent of all jobs created by those firms were attributable to their alliances.

These numbers obtained from econometric regression analysis can be extrapolated to the population. For the period from 1996 to 2001, German National Account statistics show that total employment in the knowledge-intensive sectors increased by 701,000 jobs. Based on the results of Toole et al. (2015), 453,422 of these jobs were created by 171,833 companies founded between 1996 and 2000 that survived until the end of 2001. This is about 65 percent of total net jobs in the sectors covered. Among all the startups in this cohort, it can be estimated that 51,908 companies had some kind of university connection(s) in the post-foundation period and created 223,969 jobs. Using the Heckman regression model results, Toole et al. estimate that university connections (research alliances and all others) accounted for 9.2 percent (or 20,535) of these jobs. Turning to university research alliance relationships, they

[6] Several firms within the startup population could not be contacted for interviews as they had gone out of business by the time of the survey. The sample selection model takes into account this potential source of "survivor bias," which might otherwise have led to an overestimation of the growth potential of newly founded firms.

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calculate that a total of 11,896 startups within the population had such relationships and created a total of 72,857 jobs. The model results indicate that 3.4 percent (or 2,453) jobs can be attributed to university research alliances.

These results suggest that university connections are quite important for job growth, and university research alliances contributed substantially to job creation for those firms that had such alliances.

When it comes to innovation by established firms, studies have considered spillovers from public science in general and also benefits to companies from direct interaction with public science in the form of research collaborations.

Cappelli et al. (2014) focused on “essential knowledge spillovers” that companies received from public science. While some such spillovers may be obtained from simply reading academic publications, they may also result from direct interaction through contract research or joint research collaborations. In one wave of the Mannheim Innovation Panel, firms were asked about “essential inputs for innovation” that they had received from other actors in the economy including customers, suppliers, competitors, and public science. The term “essential” was defined in the survey to mean that an input had been indispensable for the development of a new product, service or process.

Cappelli et al. related firms’ sales of market novelties to these reported spillover measures and found that essential information received from customers and public science was associated with higher sales of new products. On average, innovative firms in their sample achieved 9 percent of their sales from products that were novel in their main product market. Regression results showed that spillovers from public science pushed this share to about 13.2 percent.

In a very recent study, Comin et al. (2018) analyze the case of the Fraunhofer Association, the largest applied research public research institute in Germany. They investigate whether interacting with Fraunhofer institutes in research projects affects firms’ performance and strategic orientation. To do this, they assembled a data set based on Fraunhofer’s (confidential) internal project management system and merged it with the Mannheim Innovation Panel. They found that project interaction had a strong positive effect on firms’ turnover and productivity growth. They also showed that a major driver of these positive effects is the firms’ increased share of sales from new products and an increase in the share of their workers with tertiary education. More detailed analyses reveal, among other things, that performance effects become stronger the more often firms interact with Fraunhofer and that interactions aimed at generating technology have a stronger effect than those merely intended to implement existing technologies.

In summary, the literature has shown quite clearly that (active) knowledge transfer from public science to industry has positive effects on the business sector in Germany. The documented effects range from job creation to new product sales and productivity growth. These positive effects have been found in both startup companies (including academic startups) and established companies.

5.5 Supporting Interviews

To explore KTT in German universities in more depth, three supporting case studies including interviews were conducted for the research project on which this chapter draws – at the University of Heidelberg, Friedrich-Schiller-University (FSU) Jena, and Ludwig-Maximilian University (LMU) Munich. Table 5.11 shows some key characteristics of these institutions.

The University of Heidelberg is located in the state of Baden-Württemberg in an area characterized by a strong science base, close to many other leading scientific organizations such as:

- the German Cancer Research Institute – a research institute of the Helmholtz Society with more than 3,000 employees;
- the National Center for Tumor Diseases Heidelberg – a joint venture between the German Cancer Research Institute and the University of Heidelberg;
- the European Molecular Biology Laboratory (EMBL) – one of the world's leading research institutions and Europe's flagship laboratory for the life sciences. This is an intergovernmental organization specializing in basic research in the life sciences, funded by public research monies from more than twenty member states, including much of Europe plus Israel and two associate members, Argentina and Australia;
- the Max Planck institute for Medical Research;
- a biotechnology science park and a growing number of local biotech startups;
- the BioMed X Innovation Center, a collaboration model at the interface between academia and industry where interdisciplinary project teams conduct biomedical research in an open-innovation lab facility on the campus of the University of Heidelberg. Each team is typically sponsored by a corporate pharmaceutical or biotech partner. At the end of a fully

Table 5.11 *Key characteristics of the three case study universities*

	Heidelberg	Jena	Munich
Number of academics	444	384	747
Number of students	30,300 (including 1,300 PhDs completed per year)	19,000	48,000
Fields of study	Humanities, social sciences, law, economics, mathematics, physics, biotechnology and other natural sciences; two faculties of medicine and two hospitals; computer science	Humanities, social sciences, law, economics, mathematics, biology and other natural sciences, medicine	Humanities, social sciences, law, economics, mathematics, physics, biology, biotechnology and other natural sciences, medicine, computer science

Source: Authors

funded project term, successful projects are either internalized into the development pipeline of the respective pharmaceutical or biotech sponsor or spun off into an independent startup company.

Furthermore, several large companies are also located near Heidelberg, including BASF, SAP, Roche, AbbVie, Böhringer-Ingelheim, and Merck Serono.

FSU Jena is also located in a region with a strong science base, particularly in physics and optics. The Helmholtz institute at Jena hosts a particle accelerator, while the main optics company is Jenoptik.

LMU Munich is located near the Technical University of Munich and the Helmholtz Centre for Research on Environmental Health. Munich also hosts the headquarters of the Max Planck Association and the Fraunhofer Association plus a number of large companies such as BMW.

The three universities' KTOs share more or less the same tasks and services, such as:

- information and support for researchers regarding funding opportunities;
- handling research contracts with other research organizations, research funding organizations and the private sector;
- implementation of the university's intellectual property policy and the management of IP rights;
- management of research-based spinoff processes;
- identification of transferable IP; and
- support for research conferences and research marketing.

Interviewees said they had benefited from major public funding programs such as the Excellence Initiative and the Spitzencluster program. As a result, their KTOs gained staff, at least temporarily, helping them achieve their goals.

Furthermore, some new forms of university–industry collaboration had been implemented, for example new types of startup such as InnovationLab and the CarLa Catalytics Research Lab – laboratories either run by industry with scientific support from universities or set up as joint ventures between a firm and a university, and ideally located within a technology park on campus. Also, more hybrid labs could be established whereby industrial researchers collaborate with university researchers and the latter are partly financed by industrial partners.

While the interviewees were happy to report success stories, it became apparent that a "cultural divide" between university and industry applies to the vast majority of both university and industrial researchers, and that the lion's share of university research is largely irrelevant to the needs of business. Interviewees also mentioned that sometimes national or local businesses lack the capability to use relevant research results, but said this is not necessarily the case at the global level.

Knowledge transfer officers reported that they have inefficient technology evaluation mechanisms and that their efforts to look for patentable inventions or other forms of IP to exploit were underdeveloped.

Interviewees felt that while recent German public funding initiatives had focused on excellence, support was also necessary at the average level to boost the volume of transfer activities. By definition, only a few research units can aspire to meet the standard of scientific excellence. Furthermore, the scientific excellence criterion leads to a focus on basic rather than applied research, producing researchers with absolutely no experience of working in the business sector. Examples mentioned included engineering faculties that were developing new fields of research with less evident industry relevance than Germany's traditionally strong engineering education.

Relationships with the recently established PVAs were said to be suboptimal, complicated by their for-profit nature. However, it was also reported that knowledge transfer officers sometimes found it difficult to engage with firms as they typically had to follow strict university IP policies. This was seen as negative political pressure – the imperative to maximize license income in the short term undermined the chance to develop long-run business relationships with company partners.

In summary, the interviews confirm that efforts have been made to foster systematic KTT from science to industry in the past decade. However, a longstanding cultural divide between science and industry still inhibits knowledge exchange between them. In addition, the relatively new phenomenon of rigorous IP management by universities may have complicated bilateral agreements between universities and firms.

5.6 Conclusions

The German public science landscape is complex, with many different actors undertaking diverse KTT activities. The different types of university and different public research institutes have different missions regarding knowledge transfer.

We described the German knowledge transfer system using large-scale survey evidence from both scientific institutions and for-profit firms. Primary data collection and the analysis of secondary data provide plenty of evidence of KTT from public research organizations, ranging from patenting and licensing of inventions through to joint research projects between science and industry, contract research, exchange of personnel, and more modern forms of public–private partnerships such as shared research laboratories.

We also noted some changes in the German KTT system and considered analyses of their impact in the scholarly literature. While there is evidence that some policy measures have improved conditions for KTT, the story is not uniformly positive. The abolition of professor's privilege in the early 2000s may well have reduced academics' incentives to commercialize their inventions while the success of patent valorization agencies is moot.

Case study evidence from interviews supports our overall conclusion that policy has been trying to systematically improve the conditions for

KTT in Germany in the last two decades, and several improvements have been documented. However, policymakers need to balance the incentives for basic and applied research to ensure that Germany's science base is not hollowed out in the long run.

The challenge for universities and public research institutes is to deepen the understanding of IP and business-relevant research and applications within their institutions and to further improve communication between their researchers and industry.

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