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Research Report

Performance and Structures of the German Science System 2016

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Performance and Structures of the German Science System 2016

Rainer Frietsch, Patricia Helmich, Peter Neuhäusler

**Studien zum deutschen Innovationssystem
Nr. 5-2017**

Fraunhofer Institute for Systems and Innovation Research ISI

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0 Executive Summary

The absolute number of scientific publications continued to increase also in 2015 – a trend that holds for the whole observation period since 2005. However, growth has slowed down in the last three years, leading to partly stagnating figures across many of the countries in our sample. Thus, the majority of the worldwide growth is mainly driven by China – however, with varying effects on the other bibliometric indicators. A trade-off becomes apparent especially for countries like the USA, Switzerland and Germany, in particular when it comes to highly cited and internationally highly visible journal publications. China is also catching up in the citation based indicators like the observed citation rate, Scientific Regard, International Alignment and the Excellence Rate.

Germany's development in the short-term perspective might raise concerns about its performance. The absolute number of publications dropped by 0.6% between 2014 and 2015 and even in a longer-term perspective since 2001 it only managed an average annual growth rate of about 2.2%, while the total worldwide publications grew by 6.4%. Furthermore, the trend towards higher ranked journals continues (international alignment), but German researchers do not achieve the same citation rates within these journals (scientific regard). It becomes apparent that the additional investments in the science system since the mid 2000s – especially in the context of the High-Tech Strategy – did not yet result in considerably higher publication numbers. However, at least the excellence (top cited publications) and the average quality (in terms of citations) seem to benefit from these investments.

The growth of Chinese publications affects all scientific fields, so that in general, the influence of other countries diminishes. However, the USA still dominates the publication shares, above all in Social Sciences. China has especially high shares in Optics, chemical fields and Materials research, while Germany's main fields are Medical engineering, Nuclear technology and Physics.

With regard to the differentiation of German publications by universities and public research organizations (PROs), it can be found that the universities by far have the largest publication output in absolute terms. Among the PROs, the Helmholtz Association (HGF) has the largest publication output followed by the Max Planck Society (MPG), the Leibniz Association (WGL) and Fraunhofer Society (FHG). Yet, the publication intensities, i.e. the number of publications per FTE researcher, reveal that largest publication output per FTE researcher is achieved by the MPG, followed by the WGL and the universities. The MPG and WGL also receive the most citations per FTE, which is also resembled in their scientific regard, international alignment and excellence rates. The international co-publication trends further reveal that international collaboration has gained increased importance over the years. Similar effects can also be observed for the cooperation patterns between the PROs and universities in Germany.

Such differences have led to increasing shares in co-publications. China has in general strengthened its co-publication network, especially with the USA. The latter in turn have withdrawn from many former co-operation partners and show a high share of purely national publications in all scientific fields.

1 Introduction to this issue

The science system is an important part of any national innovation system as it not only provides basic research results that feed into further innovation processes in public research institutions and especially in enterprises, but also because it provides scientific knowledge that is of utmost importance for innovation activities in general. The scientific knowledge is generated in institutional as well as project-funded research activities, mainly public research organisation – be it universities or non-university institutions. Scientific knowledge is generated in scientific discourses, which means in exchange with and criticised by peers. One vehicle of this scientific discourse are scientific journal publications, which can be read and cited by others as well as used to built on with ones own research. The "currency" of this reception and acknowledgement are citations/references that are made to previous work. Bibliometric data analyses make use of these citations and do not only take into account the quantity or the bibliographic information – like institution, author, country or field of research – but also these citations and interpret it as a sign of visibility or even of quality of the cited publications.

In this report, the bibliometric performance of a set of 23 countries and three regions (EU-28, EU-15, EU-13) (see Appendix) is analyzed. The focus is on Germany's performance in this global context, but the content of this report has a broad and international view. Besides providing basic indicators of the publication behaviour of German scientists in an international comparison, we focus on two additional topics this year. The first one is the analysis of co-publications of German scientists in an international view. Hereby, we aim to answer the question whether international collaborations have increased across the years and which countries have become more or less important as international partners in science collaborations. In a second step, we analyze the scientific institutions in Germany by differentiating the publications by universities and the large German public research organizations, i.e. the Max-Planck Society, the Helmholtz Association, the Leibniz Association and the Fraunhofer Society.

Before digging deeper into the topic, some basic methodological remarks should briefly be discussed. Firstly, the journal publications are retrieved from the Science Citation Index Expanded (SCIE) and the Social Science Citation Index (SSCI), and conference proceedings are from the CPCI, which are all sub-products of the database Web of Science (WoS). Secondly, the analysis covers "articles", "letters", "notes" and "reviews" for journal papers, and "articles" and "proceedings" for proceeding papers. Thirdly, most analyses use fractional counting of the publications. In that way, the publications are weighted on the relative share of a country. Whole count is used for the co-publication analysis, where a fractional counting is less useful. Fourthly, as it is noted that the external citations are the most relevant for evaluative purpose, this study follows the recommendation of CWTS to exclude self-citations (Nederhof, 1993). As did previous reports in this series, the absolute numbers as well as shares of publications and citations, Scientific Regard (SR), International Alignment (IA) and the Excellence

Rate (ER) for selected countries and regions are presented. An additional analysis focuses on the German science system. We provide the number of publications and citations from German universities and non-university research institutions per full time equivalent (FTE). This year's report provides an overview of latest trends and continues most of the indicators collected in earlier years of this reporting system. To keep it concise and handy, we did not include an extensive methodological overview. Interested readers in methods are referred to Michels et al. (2013).

2 Journal publications in an international comparison

2.1 Number of publications

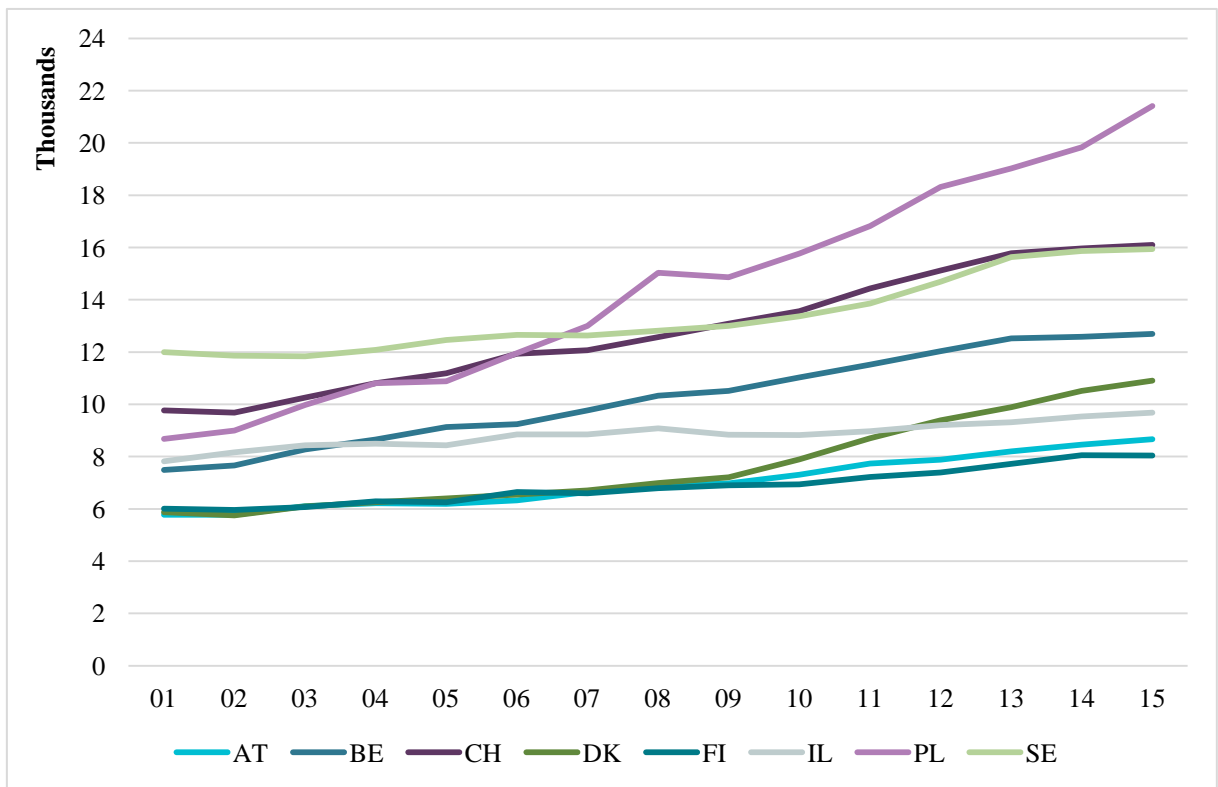
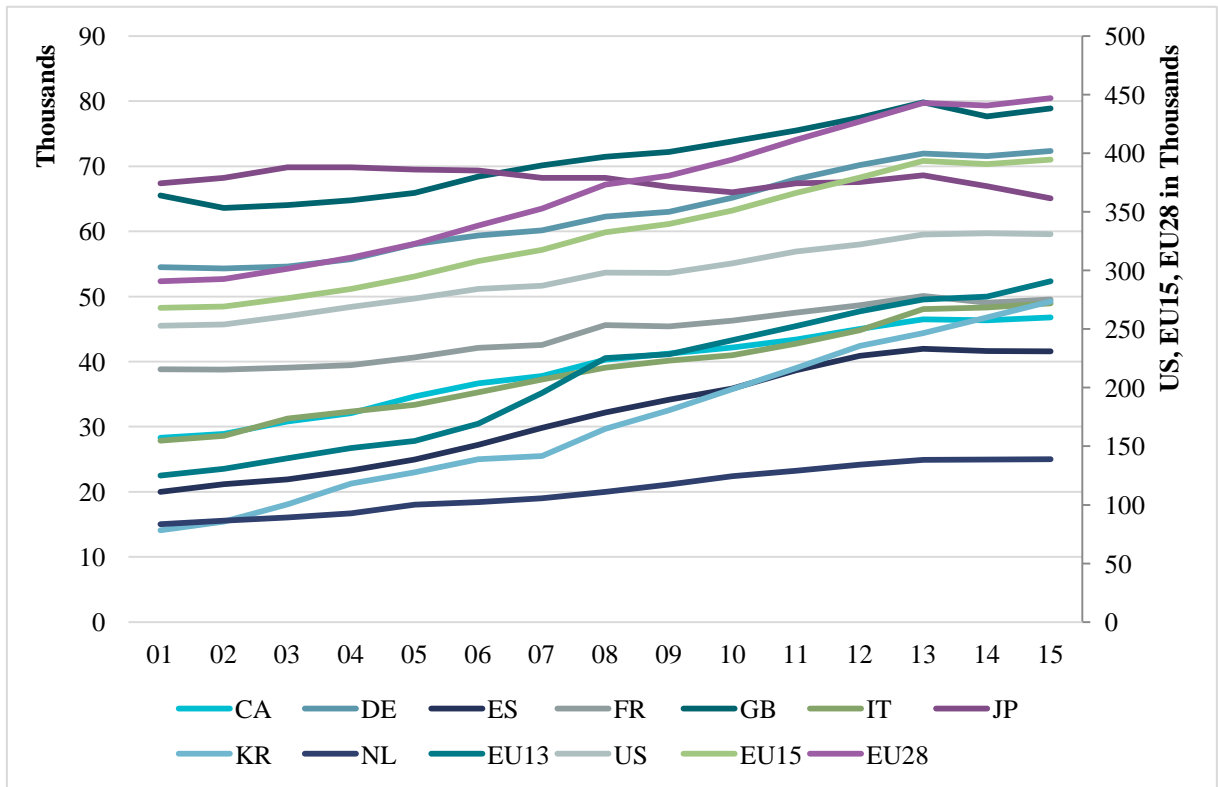
Over the past decades the number of scientific publications was growing as a result of basically three developments:

- an investment of additional resources in science systems in many countries,
- additional countries entering the stage of international sciences,
- and publications even gaining importance as an output of scientific activities.

In addition, due to growth and database effects (see e.g. Michels and Schmoch, 2012) publication numbers worldwide steadily increase in the observation period. The largest growth rates can be observed for most countries between 2008 and 2012. After 2012, however, the growth rates tend to decline, implying a less quick growth pace or even stagnations in scientific publications for most of the analyzed countries. Figure 1 shows the publication output of the selected industrialized countries in the WoS. Since the countries act on very different output levels, the graph had to be adapted to assure a good visibility for all countries: On the one hand, the EU28, the EU15 and the USA have such a high publication output that they need their own scale (right hand side in the upper figure). On the other hand, we analyse a large number of countries so that the figure was split up. Ten countries and three regions that publish most are shown in the upper figure, while the remaining industrialized countries are shown in the figure in the lower panel.

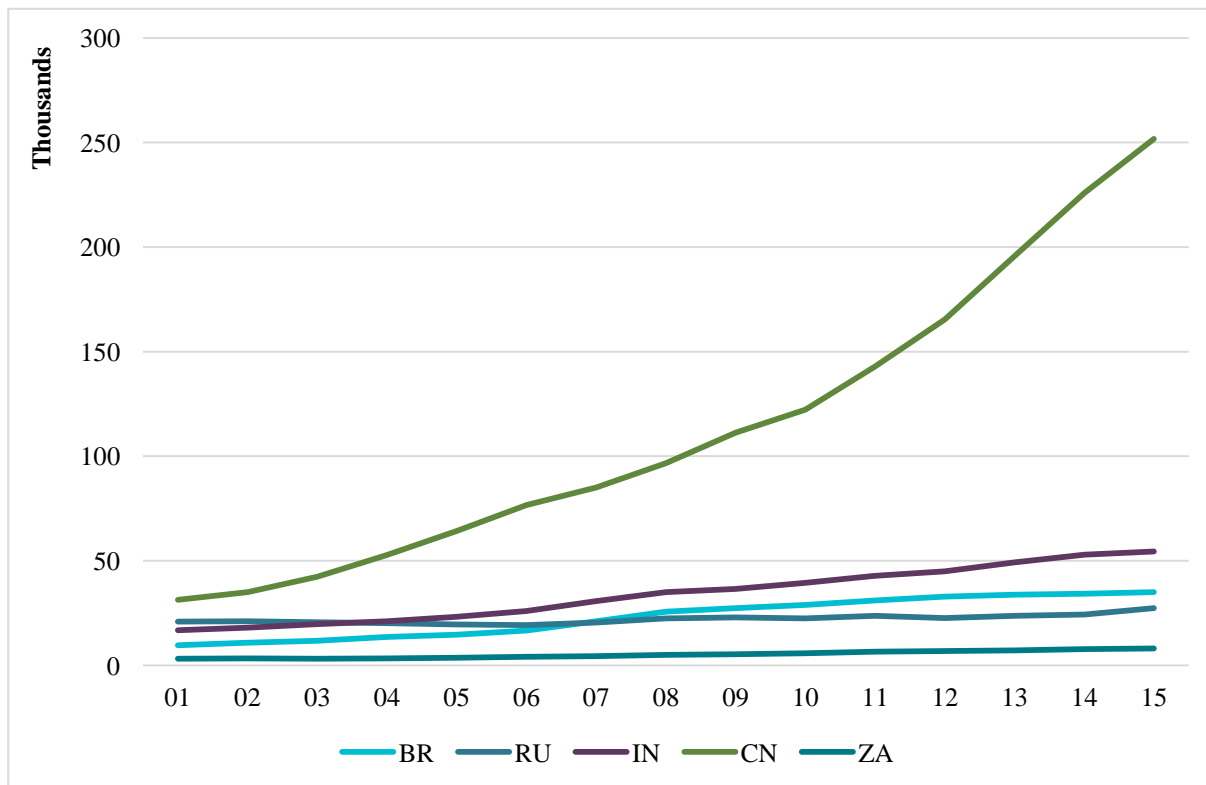
As the different scales show, the EU28, the EU15 and the USA still have an annual publication output that is far higher than those of the other countries. China is the only country that comes close to their numbers (Figure 2). Regarding only the industrialized countries, Great Britain has the second highest publication number, followed by Germany and Japan.

Figure 1: Publication numbers of the selected industrialized countries in the SCIE and the SSCI (fractional counting)



Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 2: Publication numbers of the BRICS countries in the SCIE and the SSCI (fractional counting)



Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 2 shows the publication numbers for the BRICS countries. China's publication output continued to increase quickly, reaching the level of more than 250,000 publications in sciences and technology in 2015. The compound annual growth rate (CAGR) lies at 16% between 2001 and 2015. The impressive growth even increased after 2010, not only due to a broader coverage of Asian journals in the database, but also due to an increased international orientation of Chinese researchers and a general increase in scientific capabilities in the country. The government continued to heavily invest in the public science system and also kept the incentives high for researchers to publish internationally. India and Brazil were also able to increase their absolute annual publication output, reaching CAGR levels of 9% and 10%, respectively. India meanwhile reaches a level of about 54,000 publications. Also South Africa is able to increase the absolute number of publications by more than 7% on average per year (since 2001). Similar effects can be found for Russia, however, with a CAGR of 2% since 2001, the growth is much smaller. This is one indication of a far too low investment in the science and innovation system in Russia. It seems to further lose contact with other countries and even within the group of BRICS countries – these were the promising science and innovation nations at the beginning of the 2000s – Russia seems to be decoupled from the overall trends (Schubert et al. 2013). However, all these countries (including China) still reach a level of publication output relative to their number of inhabitants that is far below the level of most

industrialised countries. In consequence, one can expect further increases of the absolute numbers also in the future.

Table 1: Development of the publication numbers of the selected countries and regions in the SCIE and the SSCI according to fractional counting (Index 2005=100)

Country/region	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
AT	100	102	107	111	113	118	125	127	133	137	140
BE	100	101	107	113	115	121	126	132	137	138	139
BR	100	113	144	175	186	197	211	224	230	233	238
CA	100	106	109	116	119	122	125	130	134	134	135
CH	100	107	108	112	117	121	129	135	141	143	144
CN	100	119	132	151	173	190	223	257	305	352	392
DE	100	102	104	107	109	112	117	121	124	123	125
DK	100	102	105	109	113	123	136	147	155	164	170
ES	100	109	119	129	137	144	155	164	168	167	166
FI	100	106	105	109	110	111	115	118	123	129	129
FR	100	104	105	112	112	114	117	120	123	121	122
GB	100	104	106	108	110	112	115	118	121	118	120
IL	100	105	105	108	105	105	106	109	110	113	115
IN	100	112	132	151	157	170	184	194	212	228	234
IT	100	106	112	117	120	123	128	134	144	145	147
JP	100	100	98	98	96	95	97	97	99	96	94
KR	100	109	111	129	141	155	170	184	193	203	214
NL	100	102	105	111	117	124	129	134	138	138	139
PL	100	110	119	138	136	145	154	168	175	182	197
RU	100	98	105	114	117	114	121	116	121	124	140
SE	100	102	101	103	104	107	111	118	125	127	128
US	100	103	104	108	108	111	114	117	120	120	120
ZA	100	113	124	140	151	161	183	194	202	220	227
EU13	100	110	127	146	148	156	163	171	178	180	188
EU15	100	104	108	113	115	119	124	129	133	133	134
EU28	100	105	109	116	118	122	128	132	137	137	138
World	100	106	111	119	124	129	137	144	152	156	161

Source: Web of Science, queries and calculations by Fraunhofer ISI

Table 1 shows the publication numbers per year in relation to the number in 2005. The worldwide increase accounts for 61% between 2005 and 2015, heavily affected by the trends in China, as well as Brazil, India, South Africa and Korea. The traditional science-oriented and industrialised countries were hardly able to considerably increase their publication output. The United Kingdom, the USA, France, Germany, Sweden and Finland published 20 to 30% more publications in 2015 than in 2005. Germany was able to increase its publication numbers by 25%. In 2006 the first implementation of the High-Tech Strategy was realised which resulted in an enormous growth of public investment also in the science system. This additional investment is visible in the accelerated growth of total scientific publication outputs between 2009 and 2012, though the largest number of additional researchers entered the system already between 2006 and 2009. The growth of the number of additional researchers was larger, however, than the growth of the publications between 2009 and 2012 resulting in slightly decreasing average numbers of publications per researcher. Explanations are time lags

between input and output, but also a stronger focus on application and innovation, which does not always result in scientific publications, but other output. On the other hand, also other countries have increased their investments in their science and innovation systems in the recent years so that an outstanding effect for Germany cannot be expected.

Several European countries were able to increase their publications even above the world average (Spain, Denmark, Poland) or close to the world average (Italy, Switzerland). Japan is the only country under observation here that even publishes fewer articles in 2015 than in 2005. The Japanese government, however, recently took action to overcome the shortcomings of the system and its involvement in international science networks. It needs to be seen, if the action takes effect. Next to the low absolute numbers of scientific publications the low level of international collaboration is a shortcoming of Japan. The government published a white book that addresses exactly this issue.

2.2 Share of publications

To better relate the numbers of the individual countries, Table 2 shows their share of the worldwide publication output. While the EU28, the EU15 and the USA still hold the highest shares in 2015, the influence of China is increasing further. Germany's share has decreased in the observation period from 5.9% to 4.6%, due to the higher growth rates in other countries.

Table 2: Shares of the selected countries and regions in percent in the SCIE and the SSCI within all publications (fractional counting)

Country/Region	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
AT	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,5
BE	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,8	0,8	0,8
BR	1,5	1,6	1,9	2,2	2,3	2,3	2,3	2,3	2,3	2,2	2,2
CA	3,5	3,5	3,5	3,5	3,4	3,3	3,2	3,2	3,1	3,0	3,0
CH	1,1	1,2	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,0	1,0
CN	6,6	7,4	7,8	8,3	9,2	9,7	10,6	11,7	13,2	14,8	16,0
DE	5,9	5,7	5,5	5,3	5,2	5,2	5,1	5,0	4,8	4,7	4,6
DK	0,7	0,6	0,6	0,6	0,6	0,6	0,6	0,7	0,7	0,7	0,7
ES	2,6	2,6	2,7	2,8	2,8	2,8	2,9	2,9	2,8	2,7	2,6
FI	0,6	0,6	0,6	0,6	0,6	0,5	0,5	0,5	0,5	0,5	0,5
FR	4,2	4,1	3,9	3,9	3,8	3,7	3,5	3,5	3,4	3,2	3,1
GB	6,7	6,6	6,5	6,1	6,0	5,8	5,6	5,5	5,4	5,1	5,0
IL	0,9	0,9	0,8	0,8	0,7	0,7	0,7	0,7	0,6	0,6	0,6
IN	2,4	2,5	2,8	3,0	3,0	3,1	3,2	3,2	3,3	3,5	3,5
IT	3,4	3,4	3,4	3,4	3,3	3,2	3,2	3,2	3,2	3,2	3,1
JP	7,1	6,7	6,3	5,9	5,5	5,2	5,0	4,8	4,6	4,4	4,1
KR	2,4	2,4	2,3	2,5	2,7	2,8	2,9	3,0	3,0	3,1	3,1
NL	1,8	1,8	1,7	1,7	1,7	1,8	1,7	1,7	1,7	1,6	1,6
PL	1,1	1,2	1,2	1,3	1,2	1,2	1,3	1,3	1,3	1,3	1,4
RU	2,0	1,9	1,9	1,9	1,9	1,8	1,8	1,6	1,6	1,6	1,7
SE	1,3	1,2	1,2	1,1	1,1	1,1	1,0	1,0	1,1	1,0	1,0
US	28,2	27,5	26,4	25,6	24,7	24,3	23,5	22,9	22,2	21,7	21,0
ZA	0,4	0,4	0,4	0,4	0,4	0,5	0,5	0,5	0,5	0,5	0,5
EU-13	2,8	2,9	3,2	3,5	3,4	3,4	3,4	3,4	3,3	3,3	3,3
EU-15	30,2	29,8	29,2	28,5	28,1	27,8	27,2	26,9	26,5	25,5	25,0
EU-28	33,0	32,7	32,5	32,0	31,5	31,2	30,6	30,3	29,8	28,8	28,4
WORLD	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0

Source: Web of Science, queries and calculations by Fraunhofer ISI

2.3 Journal-specific Scientific Regard (SR), International Alignment (IA)

The Scientific Regard (SR) and the International Alignment (IA) put the observed citation rate in perspective with the reputation of the publishing journals. While the IA shows whether a country publishes in more or less cited journals (compared with the world average), the SR relates the citation rate of a publication to the average citation rate in each journal and indexes the average for all publications.

Table 3: Index of the journal-specific Scientific Regard (SR) for the selected countries and regions in the SCIE and the SSCIE according to fractional counting

Country/Region	2005	2006	2007	2008	2009	2010	2011	2012	2013
AT	3	5	7	2	4	3	1	2	0
BE	4	5	5	6	5	4	4	3	5
BR	-20	-19	-14	-12	-11	-11	-12	-13	-14
CA	1	1	1	1	1	1	0	0	0
CH	17	15	13	14	12	11	11	9	10
CN	1	1	3	4	3	3	5	6	6
DE	9	8	7	6	5	6	5	5	4
DK	12	12	9	13	9	9	8	8	6
ES	-9	-6	-6	-7	-5	-7	-6	-6	-7
FI	-1	2	-1	-2	-1	0	0	-1	-3
FR	0	0	0	0	0	-1	-1	-1	-1
GB	7	6	5	7	7	7	6	5	4
IL	-13	-12	-11	-14	-13	-14	-13	-15	-16
IN	-13	-11	-10	-8	-7	-6	-5	-4	-4
IT	-6	-7	-6	-6	-3	-4	-4	-1	0
JP	-12	-11	-12	-12	-14	-14	-14	-14	-15
KR	-7	-6	-8	-6	-6	-7	-8	-8	-8
NL	8	8	7	8	7	8	8	8	5
PL	-21	-21	-18	-20	-16	-16	-13	-10	-8
RU	-10	-10	-7	-8	-11	-8	-9	-11	-10
SE	3	3	2	0	3	2	1	2	1
US	10	9	9	8	8	7	6	6	6
ZA	-9	-6	-7	-3	-6	-2	-8	-5	-4
EU13	-16	-14	-12	-12	-10	-9	-8	-6	-7
EU15	3	3	2	2	2	2	2	2	1
EU28	1	1	1	1	1	1	1	1	0

Source: Web of Science, queries and calculations by Fraunhofer ISI

Table 3 shows the SR values for the countries for the years 2005 to 2013. Overall, the value for Germany has been decreasing in the past century. Similar observations can be made for the EU28 countries as a whole. This holds for Austria, France, Finland and Sweden, which also show decreasing trends or which stagnate in the observation period. Of the EU28 countries, only Belgium and Italy show increasing values in 2015.

Switzerland started with an SR value of 17 in the observation period, which was one of the highest values at that time in the set of observed countries. Even though this value has been decreasing as well, Switzerland still has the highest SR value of all countries in 2015, which

means that Swiss authors get much higher numbers of citations than the average in the particular journals they are able to place their publications.

In sum, a general trend of decreasing SR values can be observed. Apart from the few EU28 countries named above, only China and India have increased their SR values at the current edge.

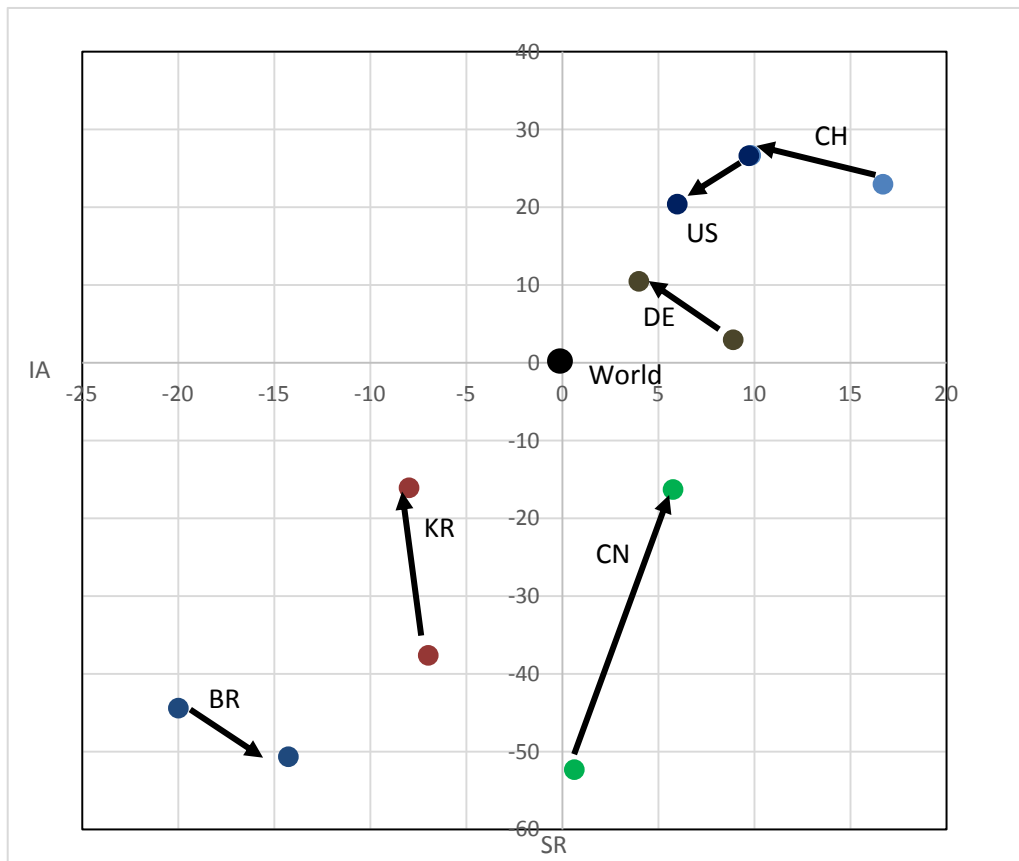
Table 4: Index of the International Alignment (IA) for the selected countries and regions in the SCIE and the SSCI according to fractional counting

Country/region	2005	2006	2007	2008	2009	2010	2011	2012	2013
AT	0	-1	2	0	-3	1	1	0	2
BE	1	2	2	3	6	2	6	7	7
BR	-44	-44	-50	-55	-56	-56	-55	-54	-51
CA	4	6	7	6	6	6	5	4	3
CH	23	22	23	25	25	25	24	27	27
CN	-52	-48	-41	-36	-32	-28	-25	-20	-16
DE	3	4	5	7	8	9	10	10	11
DK	11	13	13	15	15	15	12	12	13
ES	-13	-11	-10	-12	-11	-8	-7	-7	-7
FI	0	0	0	2	0	2	0	-1	0
FR	-3	-3	0	1	1	3	9	9	10
GB	9	8	11	13	11	11	8	9	8
IL	7	6	7	9	7	10	12	11	9
IN	-55	-49	-50	-52	-48	-48	-46	-41	-40
IT	0	0	-2	0	-2	-2	-2	-3	-3
JP	-11	-11	-10	-7	-6	-7	-4	-5	-6
KR	-38	-37	-29	-30	-29	-26	-21	-18	-16
NL	20	21	22	22	22	23	20	19	19
PL	-52	-53	-56	-61	-58	-57	-55	-56	-50
RU	-84	-83	-84	-84	-85	-84	-83	-80	-77
SE	8	8	11	9	10	10	8	6	7
USA	27	27	27	27	26	25	22	22	20
ZA	-45	-44	-46	-44	-46	-40	-46	-43	-39
EU13	-52	-50	-55	-59	-57	-56	-54	-52	-49
EU15	2	2	4	5	5	5	5	5	5
EU28	-2	-2	-1	-1	-1	0	0	0	0

Source: Web of Science, queries and calculations by Fraunhofer ISI

As a supplement to the SR values, Table 4 shows the IA values for the selected countries and regions. In general, the IA values are more dispersed than the SR values, i.e. there are countries with relatively low values (e.g. Russia, Poland and Brazil), but also with relatively high values (e.g. Switzerland, the USA and the Netherlands). Such a high disparity could not be observed for the SR values.

Figure 3: Index of the journal-specific Scientific Regard (SR) and the International Alignment (IA) for six selected countries in 2005 and 2013 in the SCIE and the SSCI according to fractional counting



Source: Web of Science, queries and calculations by Fraunhofer ISI

It is interesting to note that the two countries which increased their SR value in the observation period, i.e. China and India were also able to increase their IA value – at least in a short-term perspective. Germany however demonstrates a clear increase and thus manages to publish in journals with a higher international reputation. The SR values above indicate that the respective reference values in these journals are still (but less) surpassed.

Figure 3 shows the SR and the IA in comparison for six countries. The initial situation in 2005 as well its end situation in 2013 are depicted for each country and connected via an arrow to show the gross development. Both indicators have a value of 0 for the world, which is used as a reference point for the values of the individual countries.

Germany, for instance, starts with a relatively high SR in 2005, which diminishes during the observation period. At the same time, the IA increases from a value close to 0 to approximately 11. Thus, Germany now targets journals with a higher international reputation. It increases its visibility, aiming for journals with a higher international standing. In turn, its relative citation rate in comparison with other articles in these journals decreases. Therefore, the citation rates in these journals are overall higher and Germany cannot maintain its relatively high level in the SR.

Further countries, i.e. Switzerland, the USA, China, South Korea and Brazil were included in the graph to give some additional reference points for the German development. Switzerland and the USA, which are the only other countries in the set that also have a positive SR as well as IA value (not that the values for CH in 2013 and the US in 2005 are the same, so they show up only as "one data point" in the graph), show similar developments as Germany with regard to the SR. However, while Switzerland also manages to slightly increase its IA value, the USA loses ground also in this indicator. Therefore, they do not only show diminishing shares in the worldwide publication output (cf. Table 2), but also decrease their relative visibility of the publications.

China manages an increase in both indicators. In that way, in 2013 it has an SR value even higher than that of Germany. The IA value increases as well, so that not only journals with a higher reputation are targeted, but also higher relative citation rates are achieved. However, the citation rates are still far below the average in the respective journals.

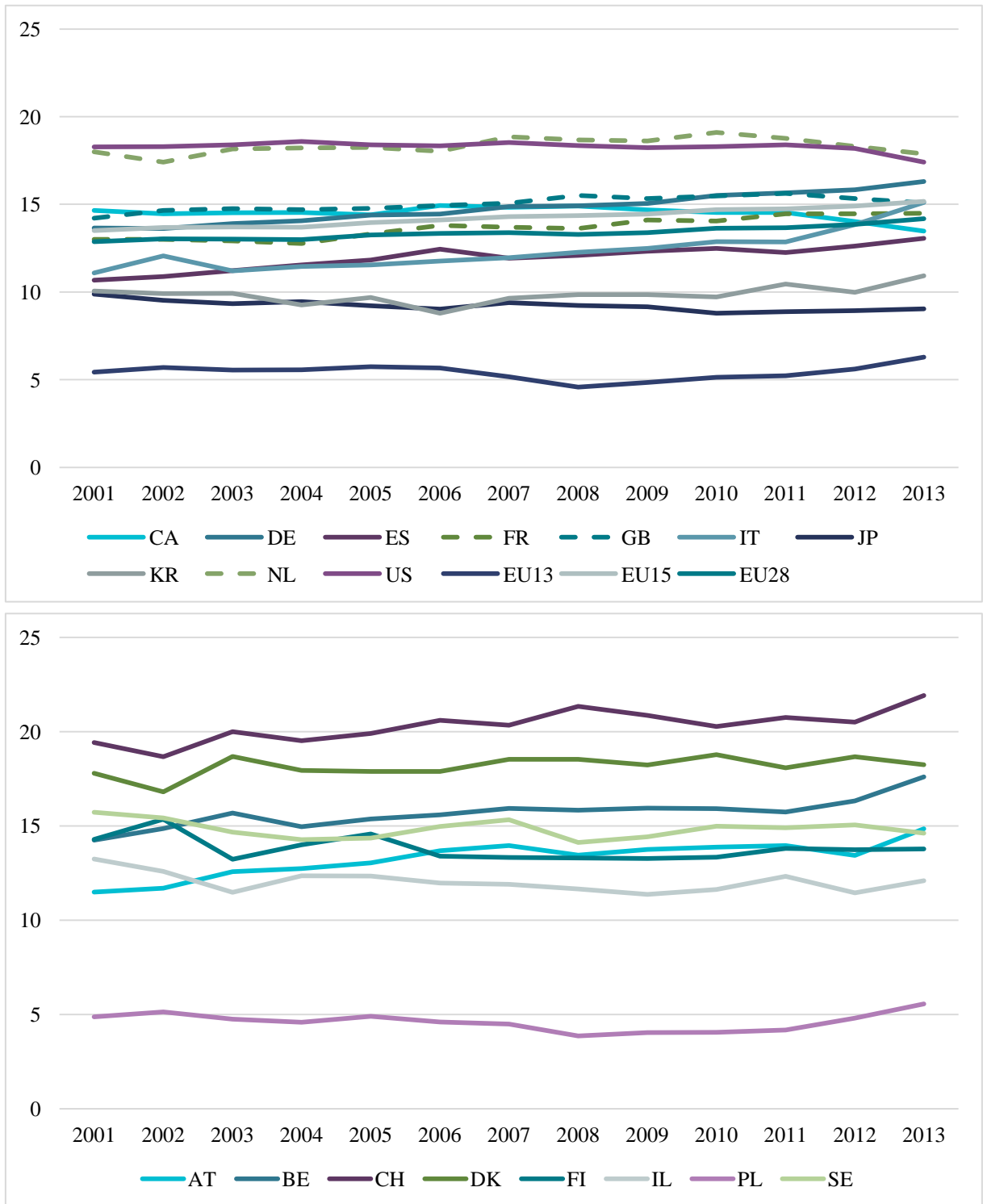
2.4 Share in top cited publications (Excellence Rate)

In this section, the share of publications that belong to the worldwide top cited publications is analyzed. For that purpose, in a first step the 10% top cited publications per field (to account for varying citation rates in the scientific fields) are selected. For each country, the number of publications belonging to the top 10% in at least one field is calculated and set in relation to the total number of its publications. In that way, its share of highly cited publications is derived, that is also denoted as Excellence Rate (Bornmann et al., 2012; Waltmann and Schreiber, 2013).

Figure 4 shows the Excellence Rate for the industrialized countries. Only few of them do not reach the reference value of 10%. The Polish publications and the publications of the EU13 countries are only around 5% of the cases in the set of highly cited publications. Japan and South Korea are close to the 10% mark, the latter even tops it in the last years.

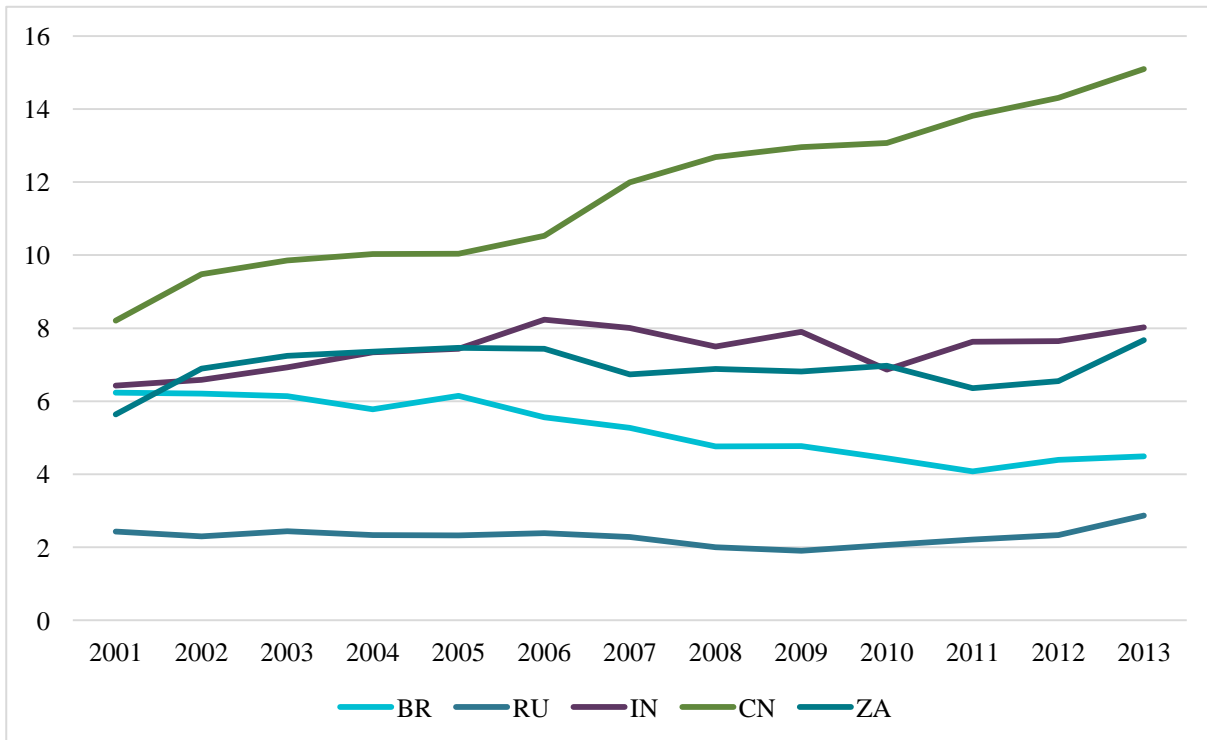
In comparison, the BRICS countries have – again with the exception of China - relatively low values (Figure 5). China achieves values far higher than the other BRICS countries and shows a steep increase after 2006. This again stresses the impressive trend that China managed not only to increase its absolute numbers of publications considerably, but at the same time also increased its quality and visibility of the publications. This, however, needs to be balanced by the fact that national preferences exist – not only in China, but also in the USA, for example – to read and cite publications by researchers from the same country (see e.g. Gondal, 2011). In consequence of the strong increase in publications by Chinese authors, the increase of citations is not that astonishing, given the large absolute number.

Figure 4: Excellence Rate for the industrialized countries according to fractional counting for the years 2001 to 2013



Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 5: Excellence Rate for the BRICS countries according to fractional counting for the years 2001 to 2013



Source: Web of Science, queries and calculations by Fraunhofer ISI

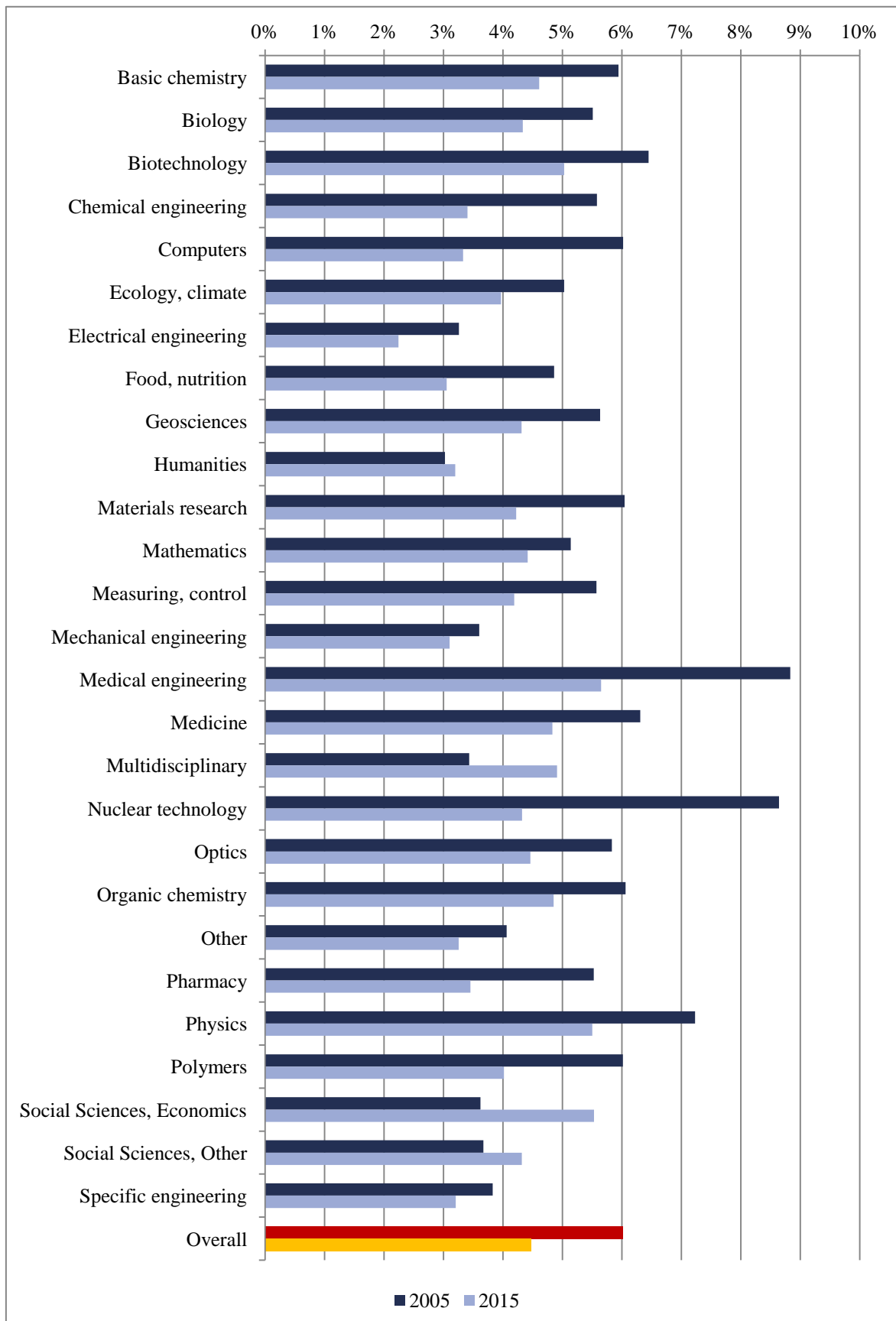
3 Structural analyses

In this part, the publications and their respective indicators are classified according to the 26 scientific fields. In that way, the scientific profile of the countries can be shown over time and in comparison to each other. Germany is compared with China and the USA.

3.1 Shares of publications in the fields

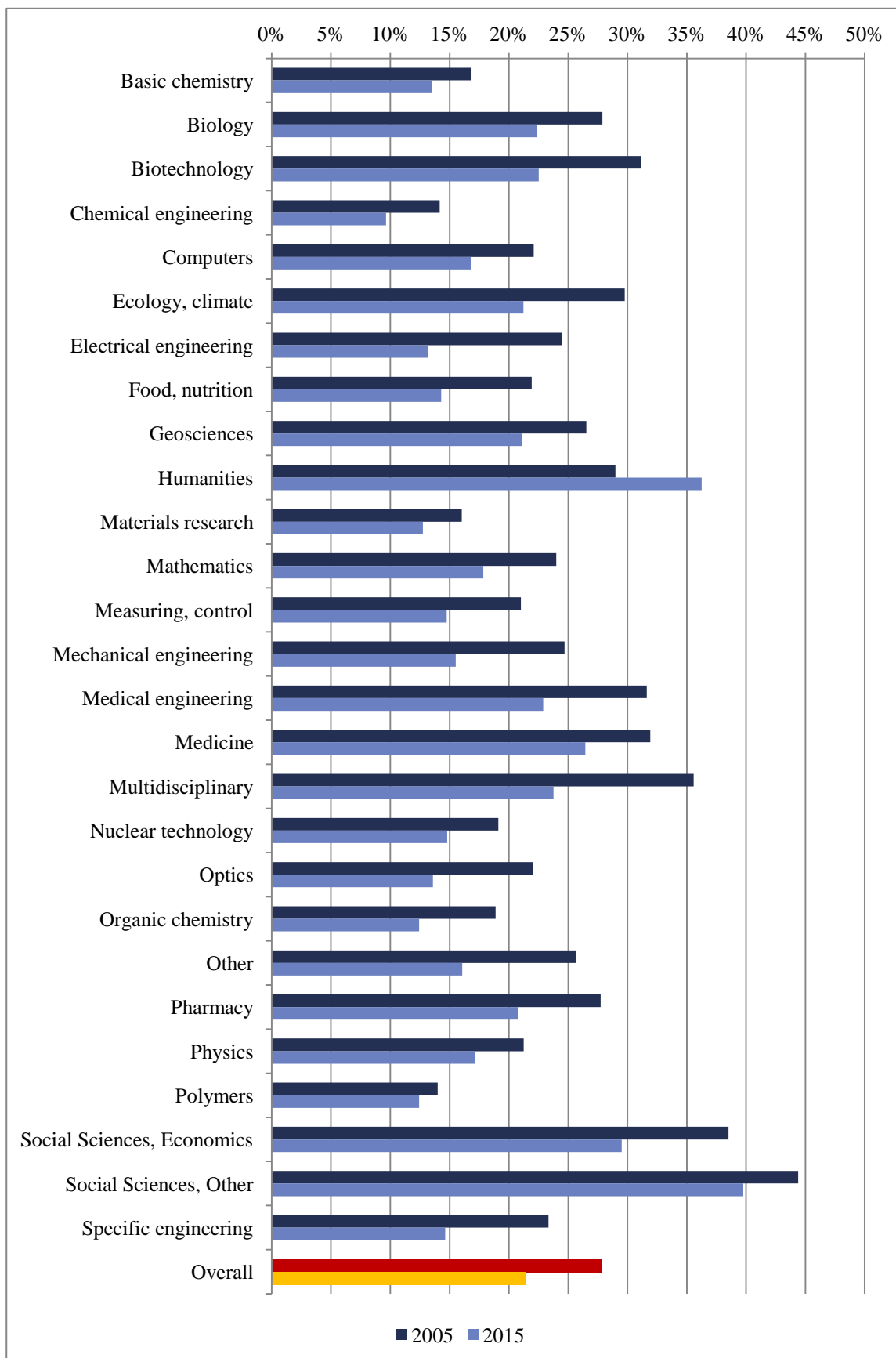
In a first analysis, the shares of Germany, the USA and China in the worldwide publication output in the 26 fields are depicted (Figure 6, Figure 7 and Figure 8). Germany has – in comparison to the USA – a smaller share of total publication output. The main fields, in which it is represented internationally, are Medical engineering, Nuclear technology and Physics. The USA especially dominates the Social Sciences although the shares decreased during the two observation periods. In 2005, more than 40% of the respective publications came from the USA. This share has now decreased to slightly less than 40%. Both the USA as well as Germany have lost shares in many scientific fields, while China has increased the respective values with no exception. Especially Optics, Chemical fields and Materials research now show relatively high shares of China.

Figure 6: Germany's worldwide shares by fields for publications in the SCIE and the SSCI according to fractional counting for the years 2005 and 2015



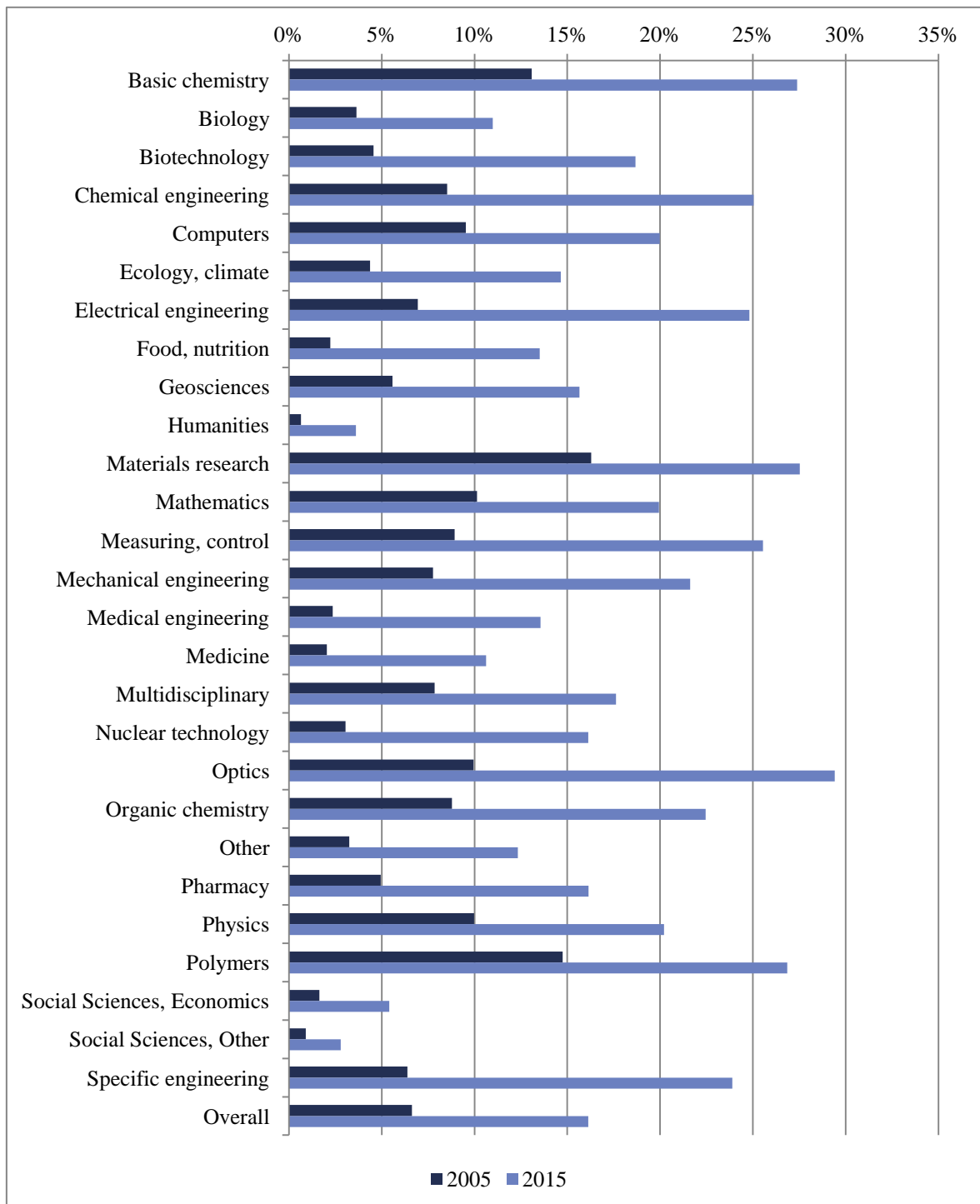
Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 7: USA's worldwide shares by fields for publications in the SCIE and the SSCI according to fractional counting for the years 2005 and 2015



Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 8: China's worldwide shares by fields for publications in the SCIE and the SSCI according to fractional counting for the years 2005 and 2015

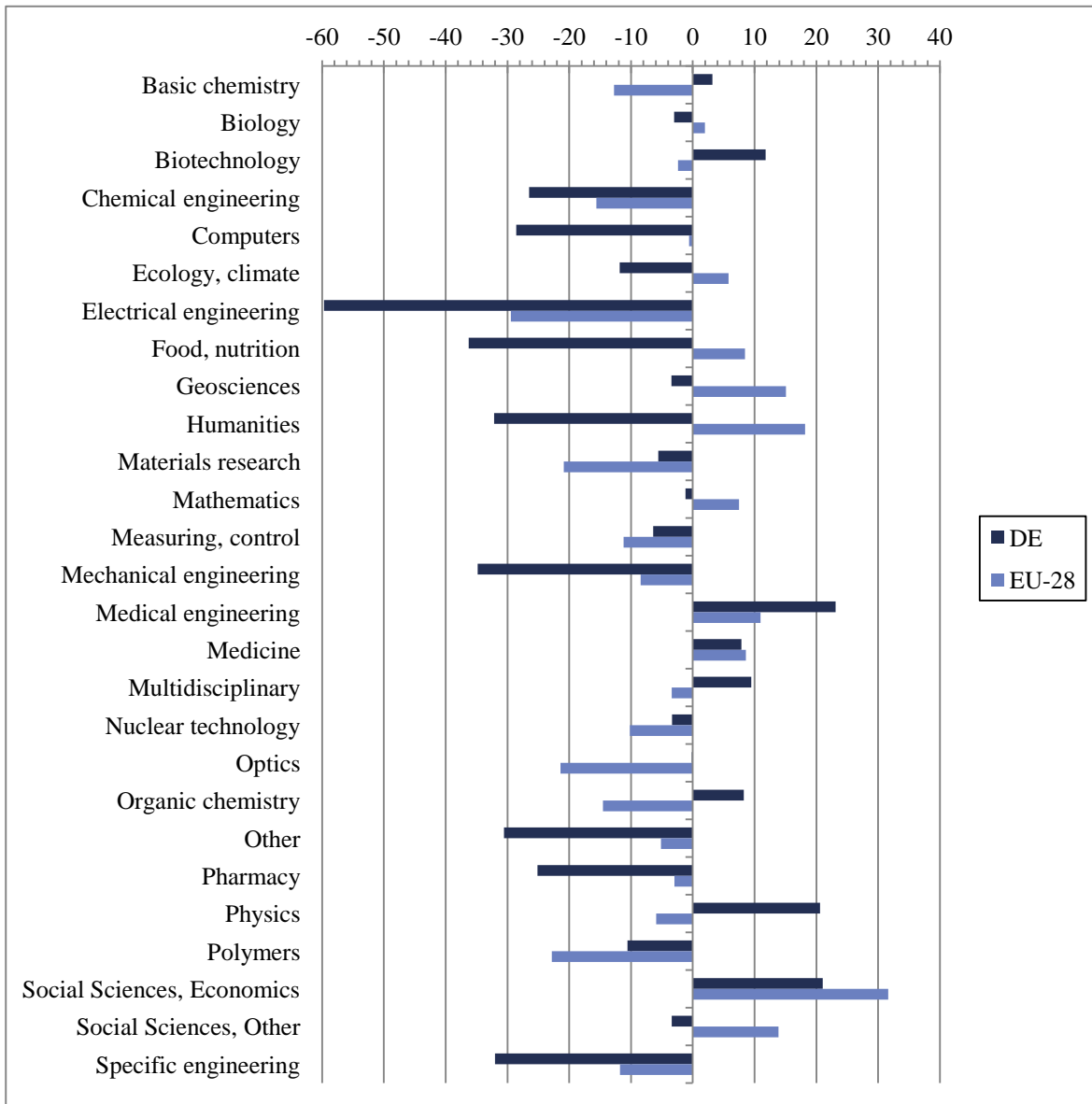


Source: Web of Science, queries and calculations by Fraunhofer ISI

3.2 Revealed Literature Advantage

In contrast to the foregoing analysis, the Revealed Literature Advantage relates the shares of a field in a country to the share of that field in worldwide publications. The scale is normalized to values between -100 and +100.

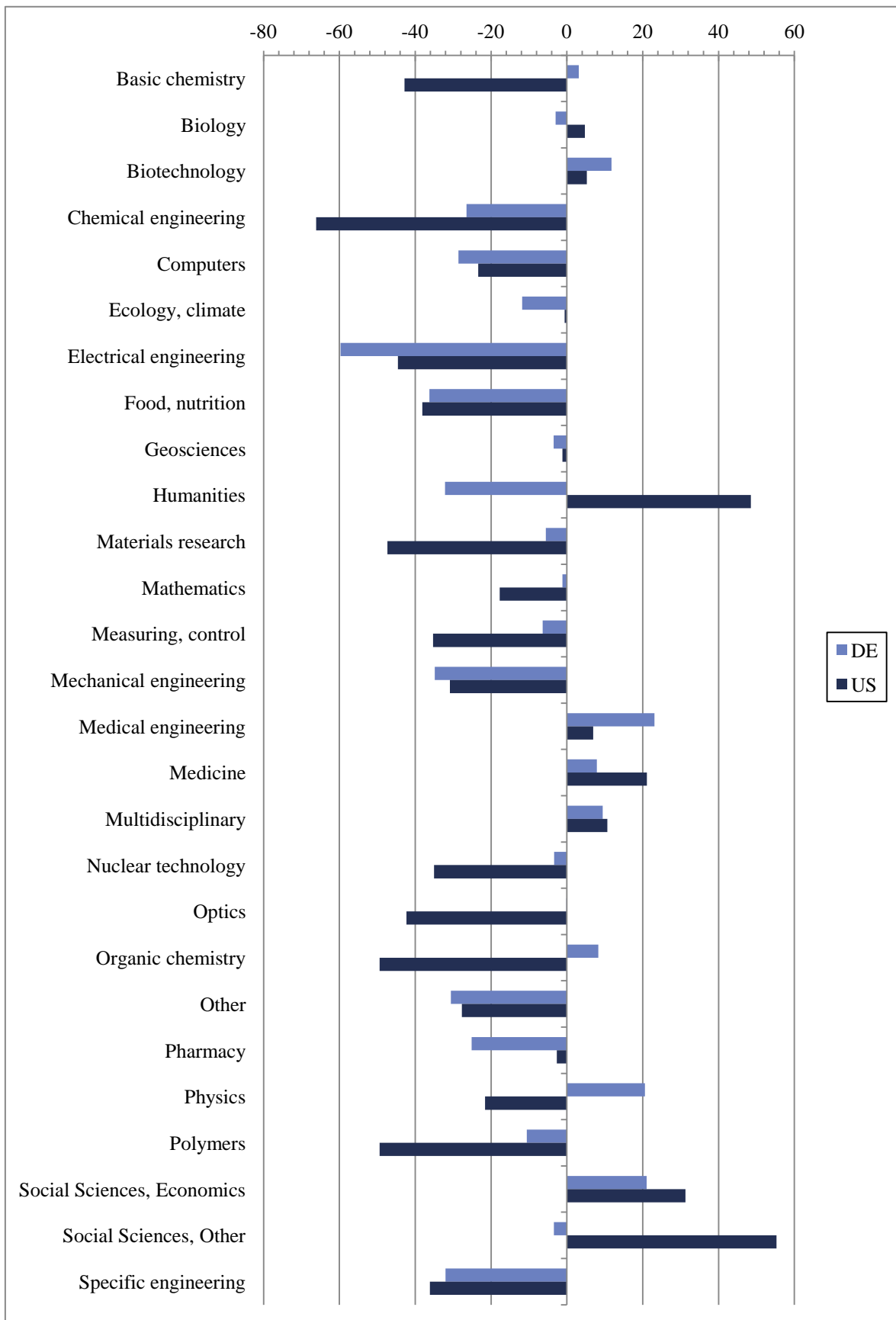
Figure 9: RLA of Germany and the EU28 for publications in the SCIE and the SSCI according to fractional counting in the year 2015



Source: Web of Science, queries and calculations by Fraunhofer ISI

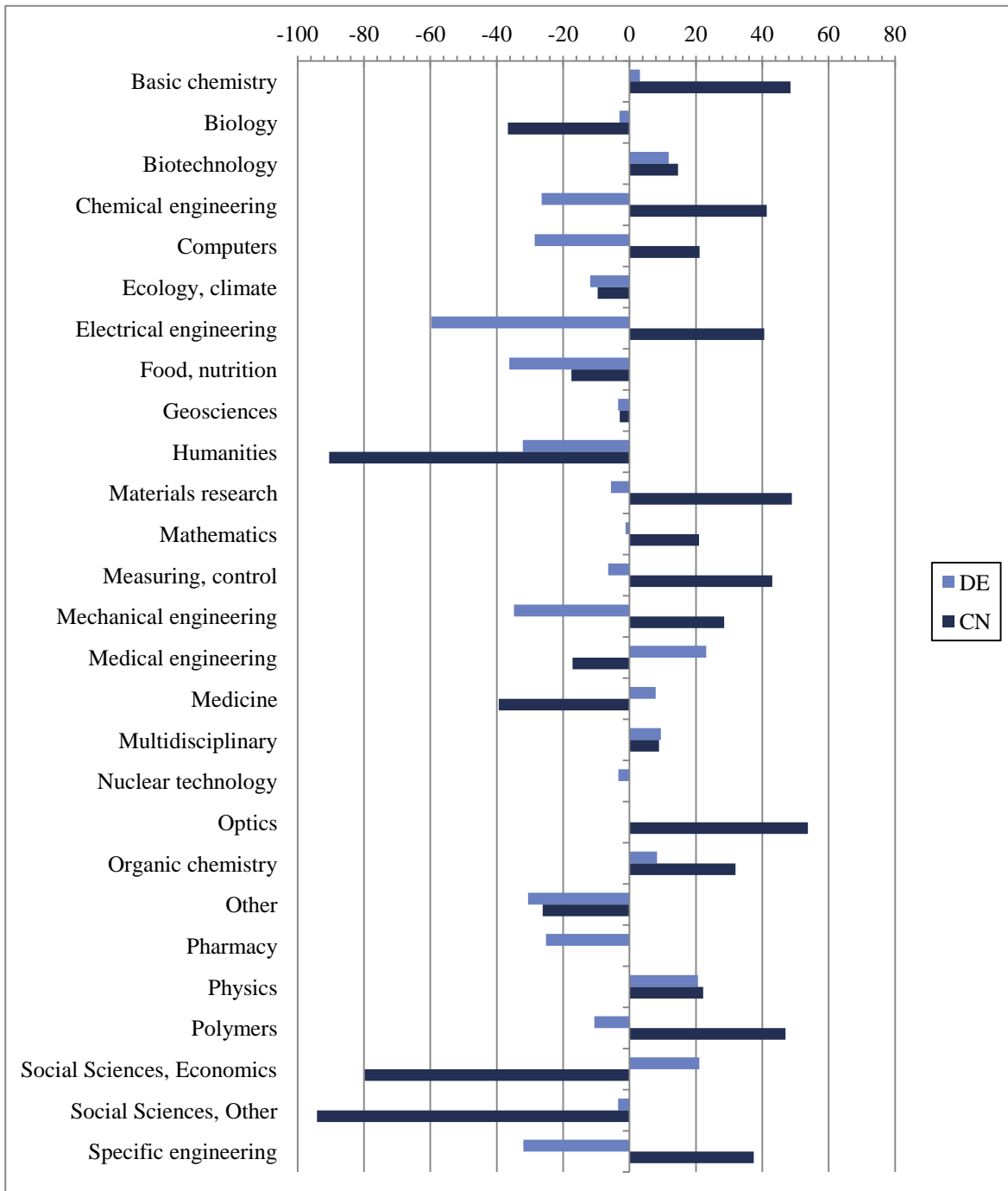
In Figure 9, the RLA values of Germany are compared to that of the EU28 countries. Germany again excels in fields like Medical Engineering, Physics and Biotechnology, but shows relative low specialization values in Electrical and Mechanical engineering. Some opposing trends for Germany and the EU28 countries can be found; for instance, fields like Food, nutrition or the Humanities are relatively less represented in German publications than in those of the EU28. In comparison to the USA (Figure 10), Germany’s focus is set more on technical fields than humanities and social sciences. In contrast to that, China’s scientific profile is most prolific in fields like Chemistry and Engineering (Figure 11). In the direct comparison, the profile of the USA is very similar to that of Germany with only few exceptional fields, while the one of China is very different.

Figure 10: RLA of Germany and the USA for publications in the SCIE and the SSCI according to fractional counting in the year 2015



Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 11: RLA of Germany and China for publications in the SCIE and the SSCI according to fractional counting in the year 2015

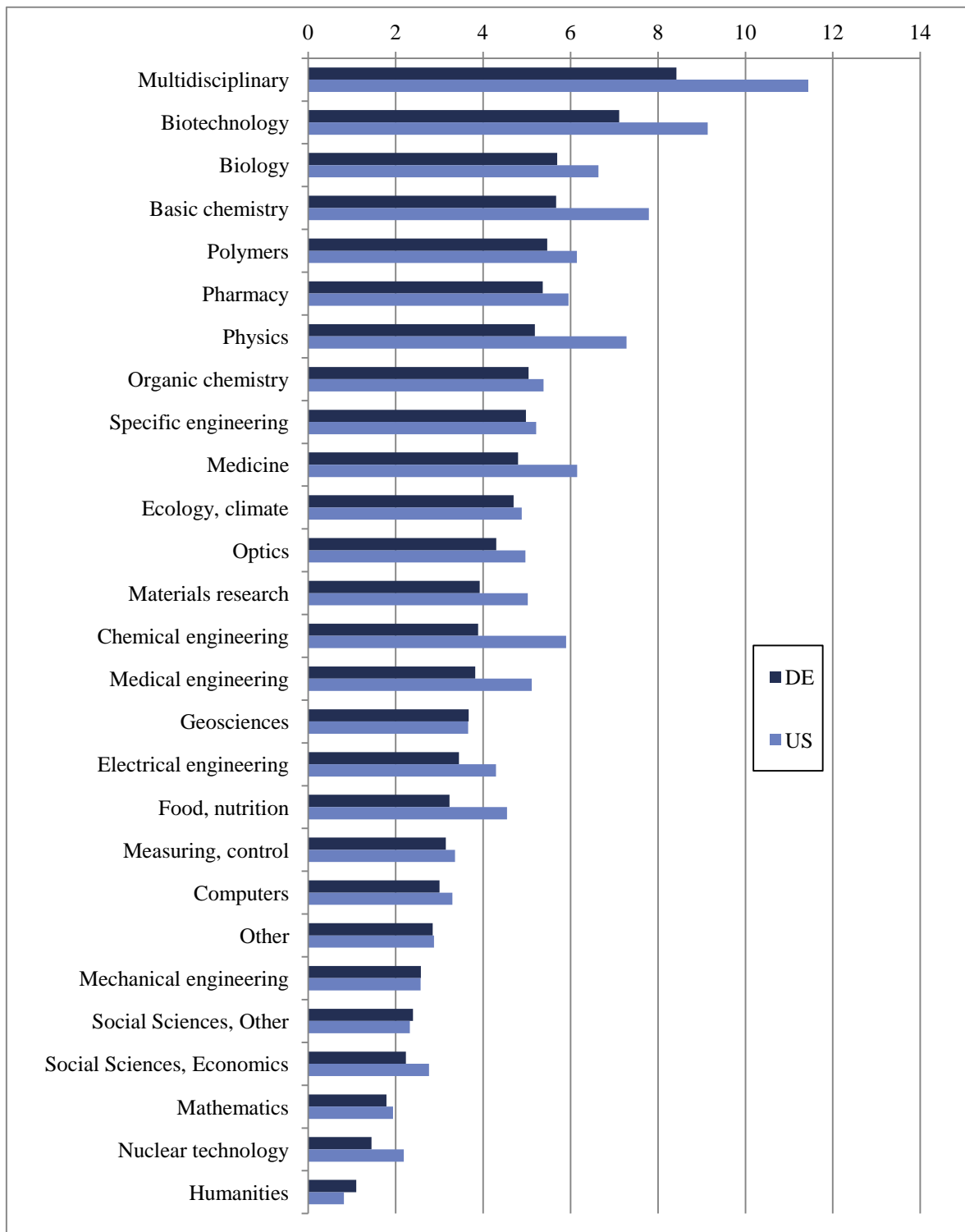


Source: Web of Science, queries and calculations by Fraunhofer ISI

3.3 Citation-based indicators

In general, the citation rates of the USA are higher than those of Germany in all fields. In the multidisciplinary fields, as well as Biotechnology, Basic chemistry, Physics, Medicine, Materials research, Food, nutrition and Chemical engineering, the difference is far higher than in the other fields. The field for which Germany has higher citation rates are Humanities and Social Sciences (not economics).

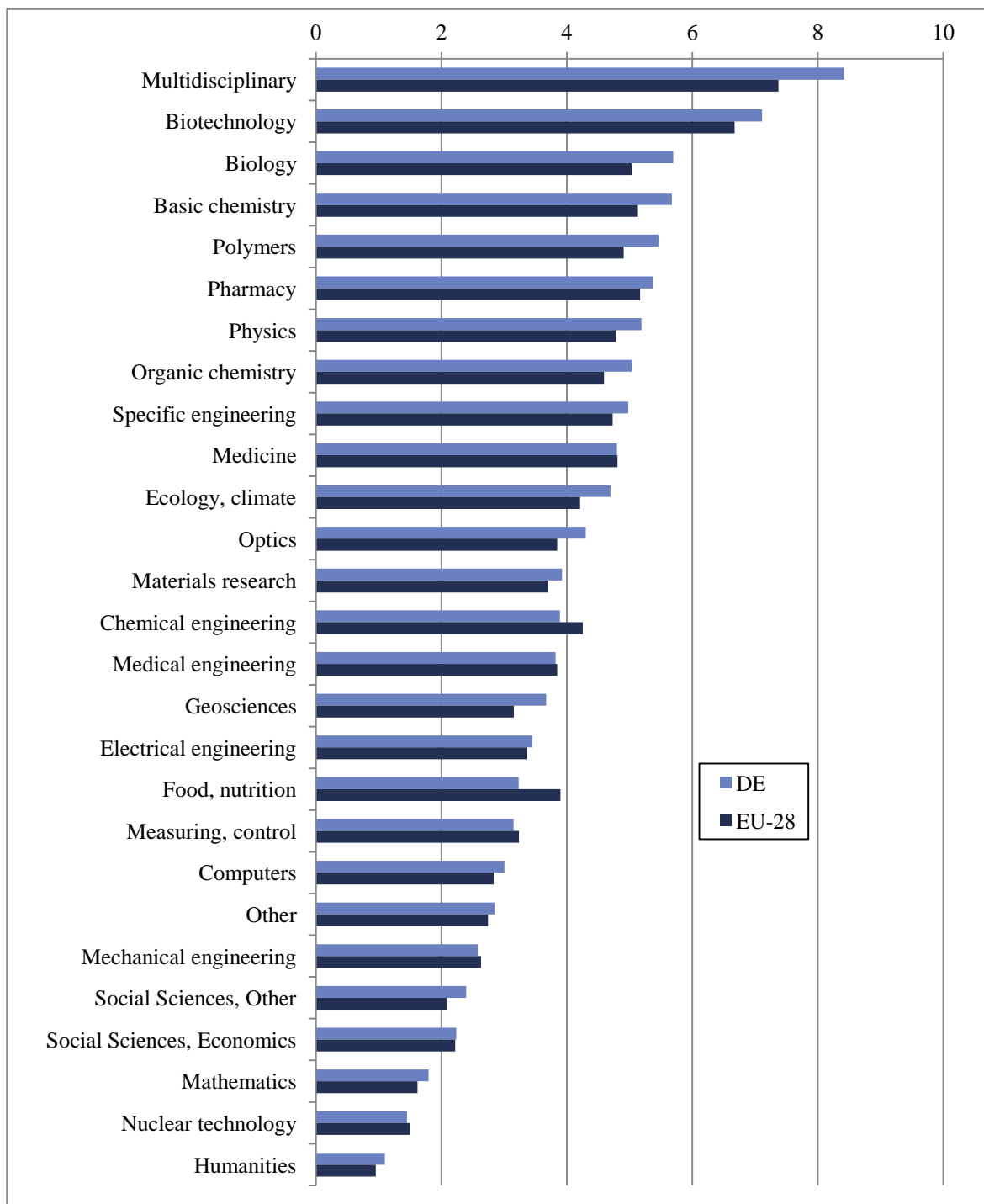
Figure 12: Citation rate per field of Germany and the USA for publications in the SCIE and the SSCI in 2013 according to fractional counting



Source: Web of Science, queries and calculations by Fraunhofer ISI

Yet, Germany has in comparison with the EU28 countries in general a relatively high citation rate across most of the fields. Here, the only exceptions are Food, nutrition, Chemical and Medical engineering, Measuring, Control, Mechanical Engineering and Nuclear Technology (Figure 13).

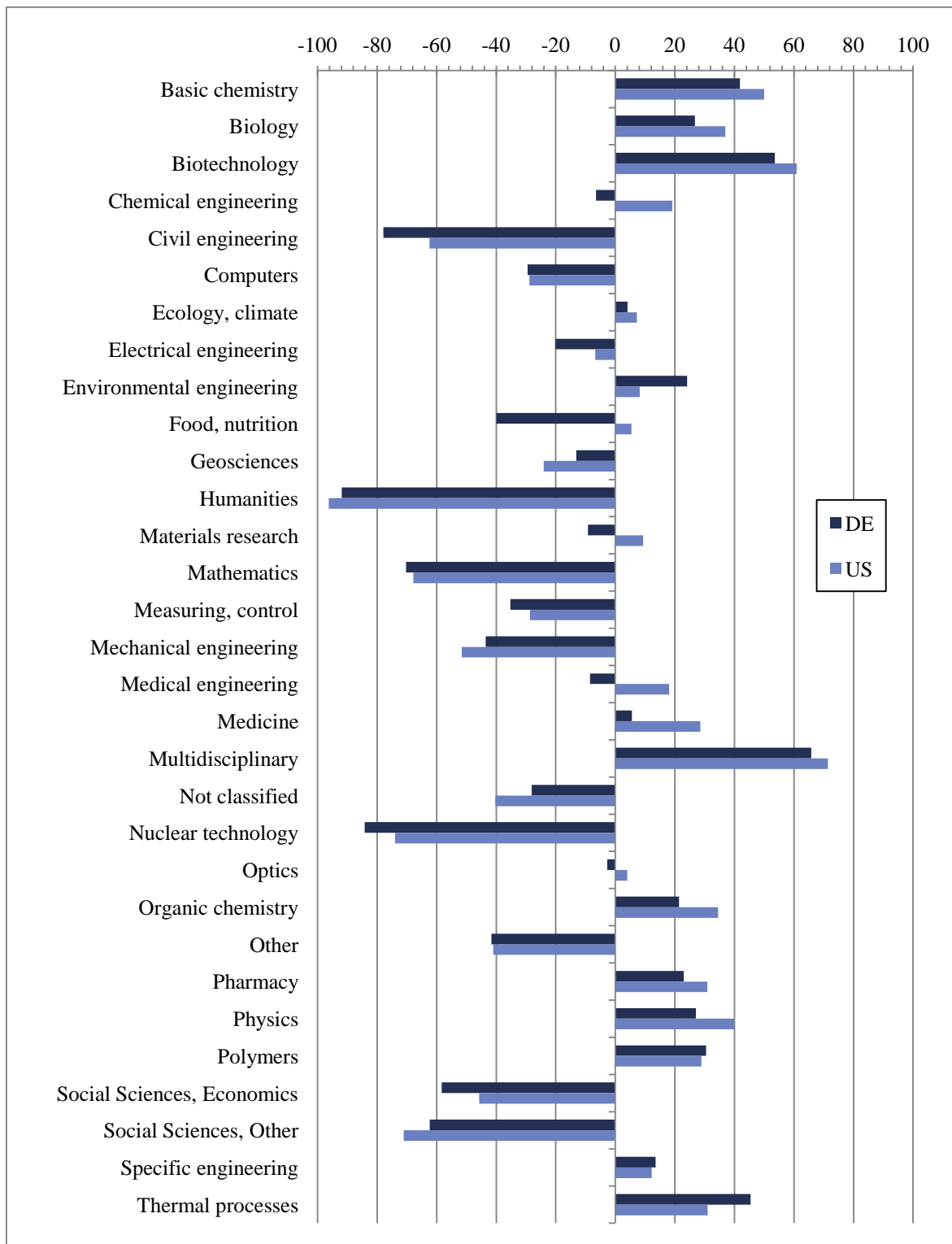
Figure 13: Citation rate per field of Germany and the EU28 for publications in the SCIE and the SSCI in 2013 according to fractional counting



Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 14 to Figure 17 show the IA and SR index of Germany, China and the USA for the 26 fields in comparison. Again, the USA and Germany share a very similar profile. Since the IA is calculated based on a comparison to the worldwide average citation rate, it can be expected to show negative values in fields with a general low citation rate, e.g. the Social Sciences. Therefore, similar values can be expected. Also in this indicator, the field Food, nutrition, in which Germany publishes relatively seldom, deviates negatively.

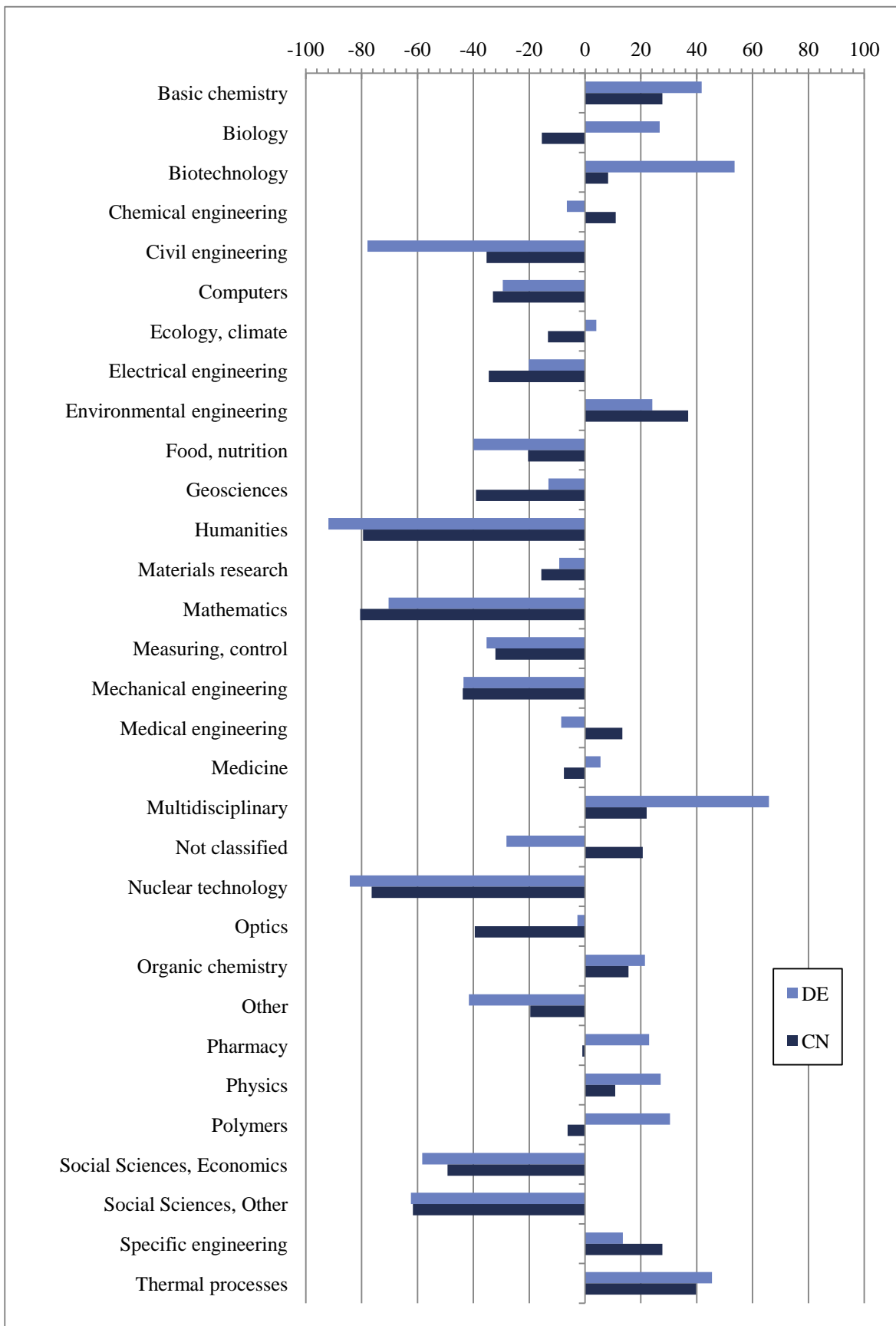
Figure 14: IA per field of Germany and the USA for publications in the SCIE and the SSCI in 2013 according to fractional counting



Source: Web of Science, queries and calculations by Fraunhofer ISI

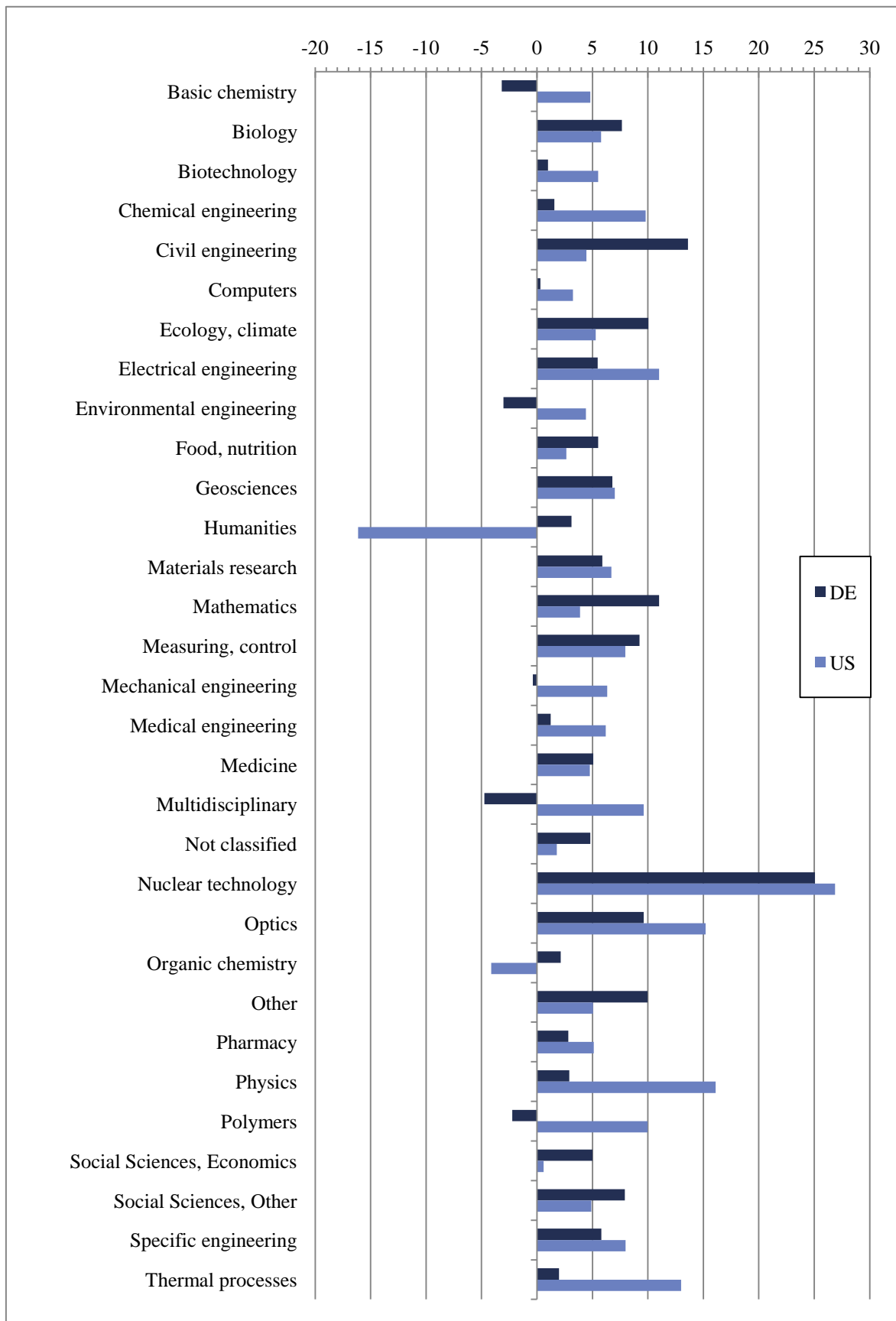
As was already to be expected based on the aggregated IA value shown above, China has a negative IA value for most of the fields (Figure 15). In most of them, it manages to be cited more often than other publications in the respective journals (Figure 17).

Figure 15: IA per field of Germany and China for publications in the SCIE and the SSCI in 2013 according to fractional counting



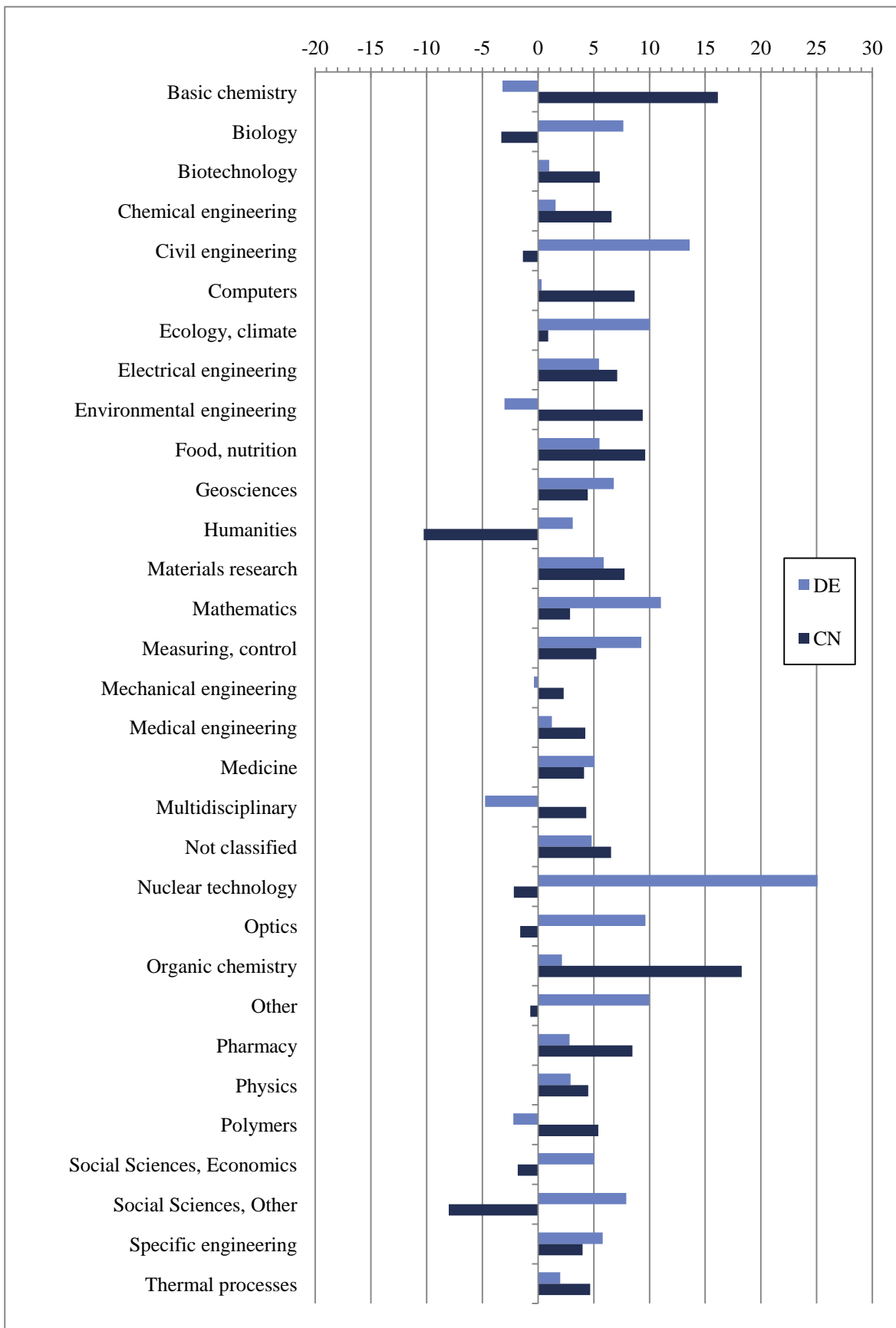
Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 16: SR per field of Germany and the USA for publications in the SCIE and the SSCI in 2013 according to fractional counting



Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 17: SR per field of Germany and China for publications in the SCIE and the SSCI in 2013 according to fractional counting



Source: Web of Science, queries and calculations by Fraunhofer ISI

4 Co-publication analysis of Germany and the EU

International exchange, particularly in the sciences, has become an important part of scientific work and, in some fields, even essential in the field of knowledge and the application of new knowledge. The internationalization strategy of the Federal Government from 2008 still is in force and is primarily aimed at strengthening cooperation with the scientifically best in the world, and on the other hand making the worldwide potential for innovation available to Germany.

International co-publications are defined as publications with authors from different countries. Analyzed over time, the cooperative structures can indicate the internationalization of research and development activities and provide information on the countries where the most important cooperation partners in specific fields of German scientists originate.

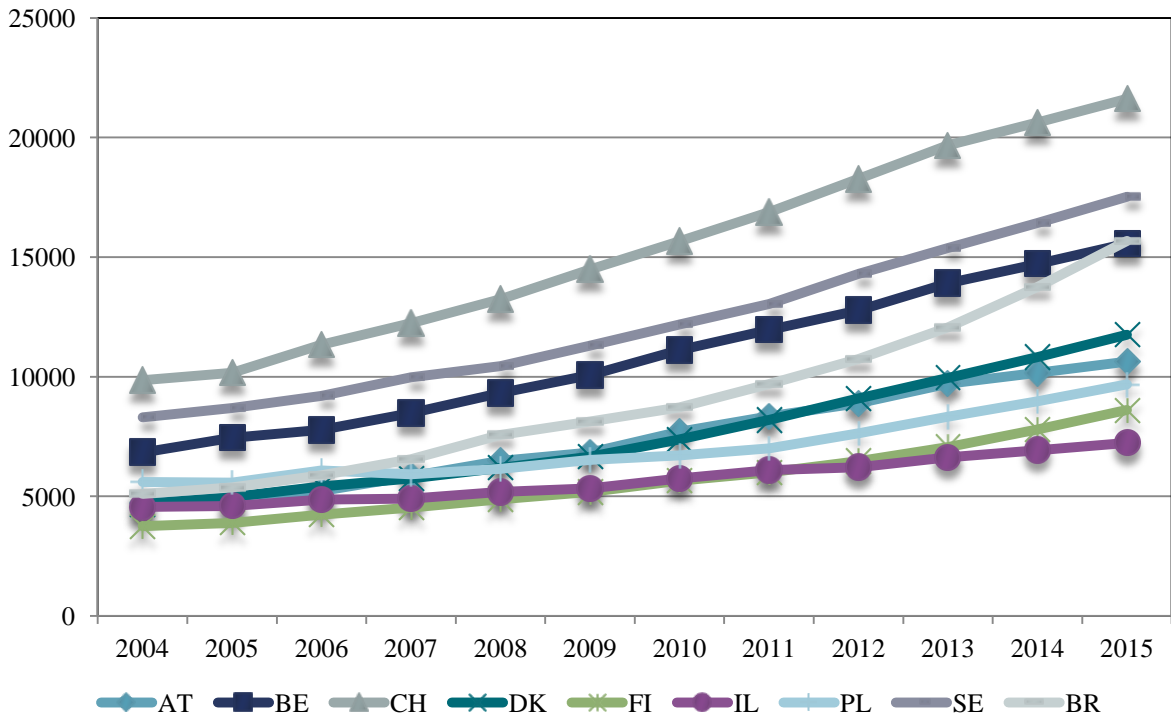
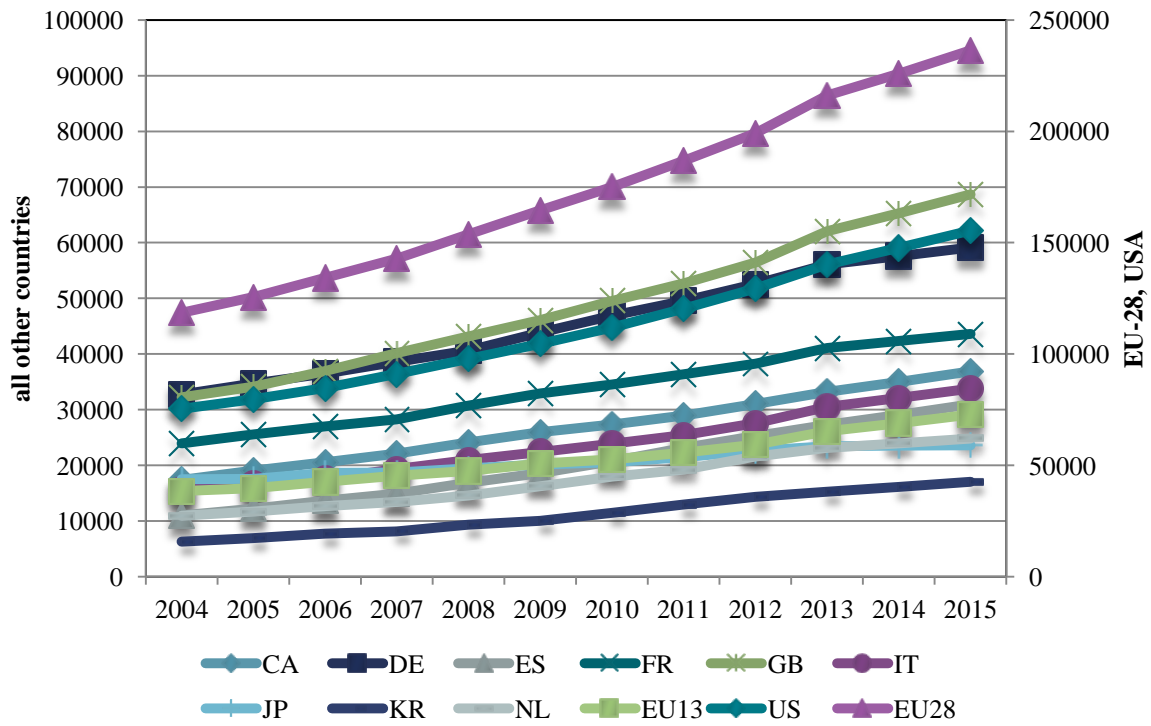
International co-publications are able to reflect international collaborations between institutions from different countries, thereby giving an indication of international knowledge exchange and internationally acknowledged scientific knowledge. Based on co-publication data networks and collaboration patterns between countries can be analysed, using the author addresses listed on the publications. The main aim of the analysis provided in this section is to examine the international co-publication profile of Germany and selected partner countries.

4.1 Co-publication analysis for countries and areas

The absolute number of international co-publications of selected countries is depicted in Figure 18. The EU-28 countries are not only the largest scientific area in the world, but also the one with the highest number of international co-publications (including publications within EU-28 countries). Second ranks in this indicator also the USA, followed by the United Kingdom and Germany, with almost 70,000 or 60,000 co-publications respectively. The absolute numbers for the BRICS countries are provided in Figure 19. It can be seen that all countries exhibit a similar dynamic trend, except for Russia, which developed much slower and just recently increased the absolute number of international co-publications faster.

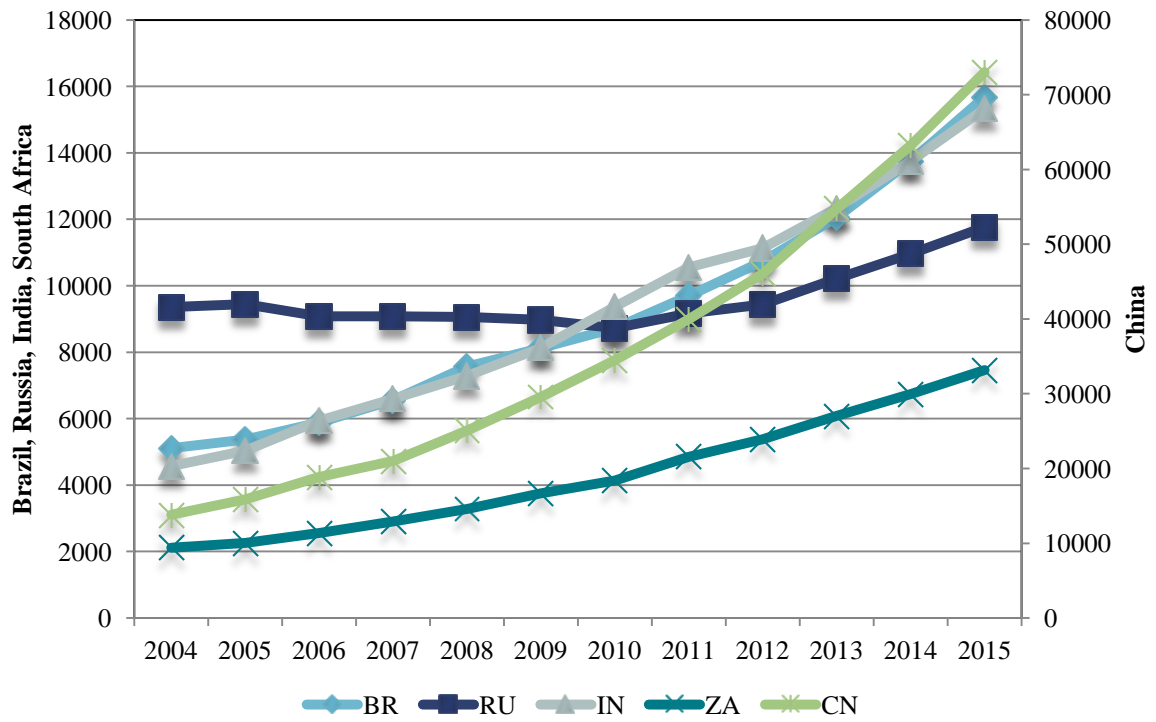
The shares of international co-publications in total national publications are presented in Figure 20 and Figure 21. Almost all countries increased their shares of international co-publications during the observation period. However, Asian countries – South Korea, Japan, but also China, India and also Russia – reach the lowest shares and also show the least dynamic trends in international co-publications. The highest shares can be found for the smaller European countries, namely Switzerland, Austria, Belgium, but also the Netherlands. Among the larger countries France and the United Kingdom – due to language reasons and still existing relations to their former colonies – reach rather high shares of about 60%. Germany recently reached a level of 55%, which is due to intensive worldwide collaborations, but first and foremost due to co-publications with European neighbour countries.

Figure 18: Number of international co-publications of the selected industrialized countries according to whole-count numbers for the years 2004 to 2015



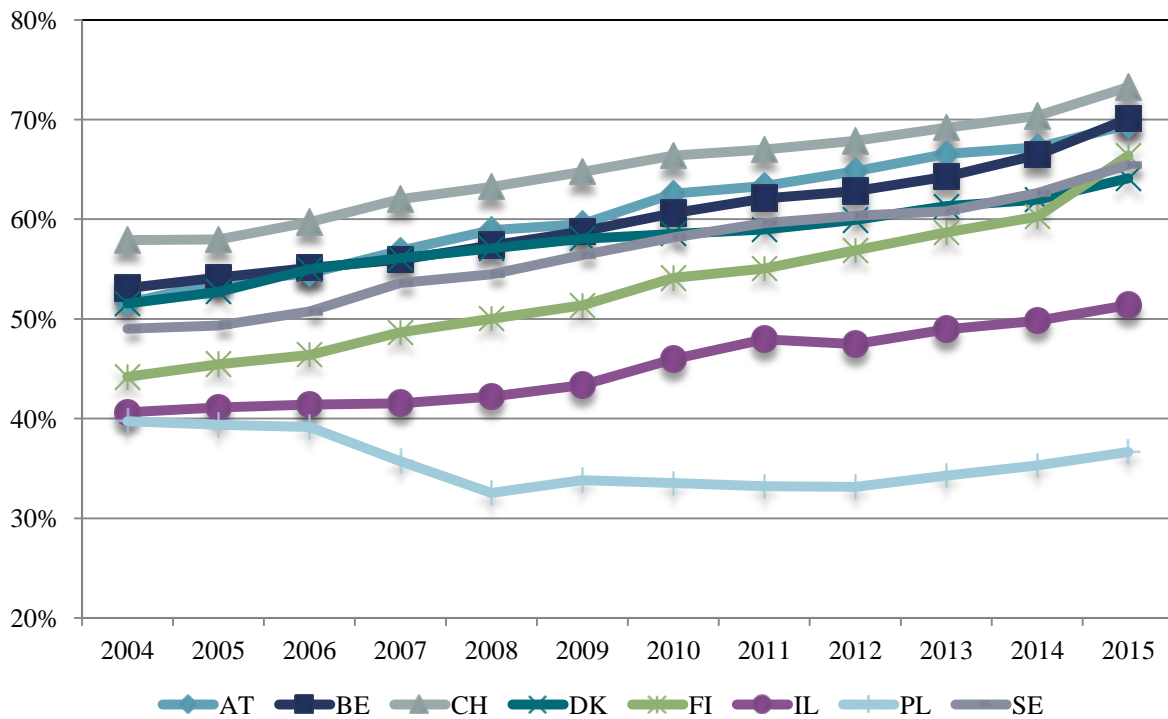
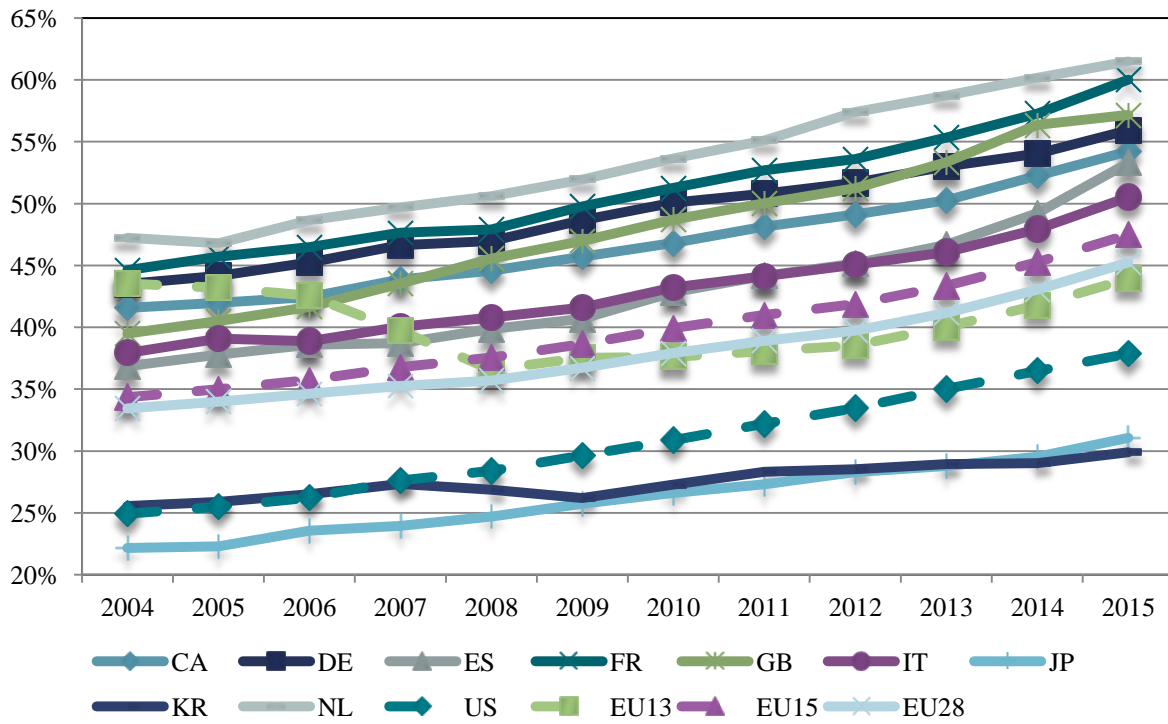
Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 19: Number of international co-publications of the BRICS countries according to whole-count numbers for the years 2004 to 2015



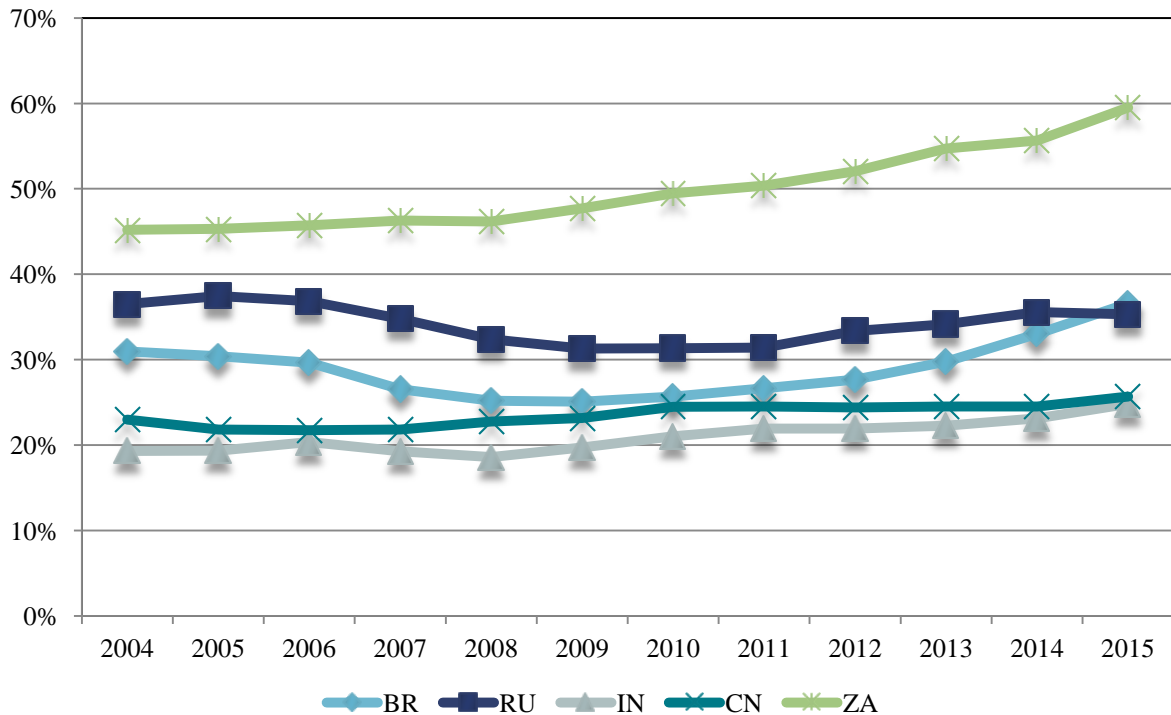
Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 20: Share of international co-publications of the selected industrialized countries according to whole-count numbers for the years 2004 to 2015



Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 21: Share of international co-publications of the BRICS countries according to whole-count numbers for the years 2004 to 2015



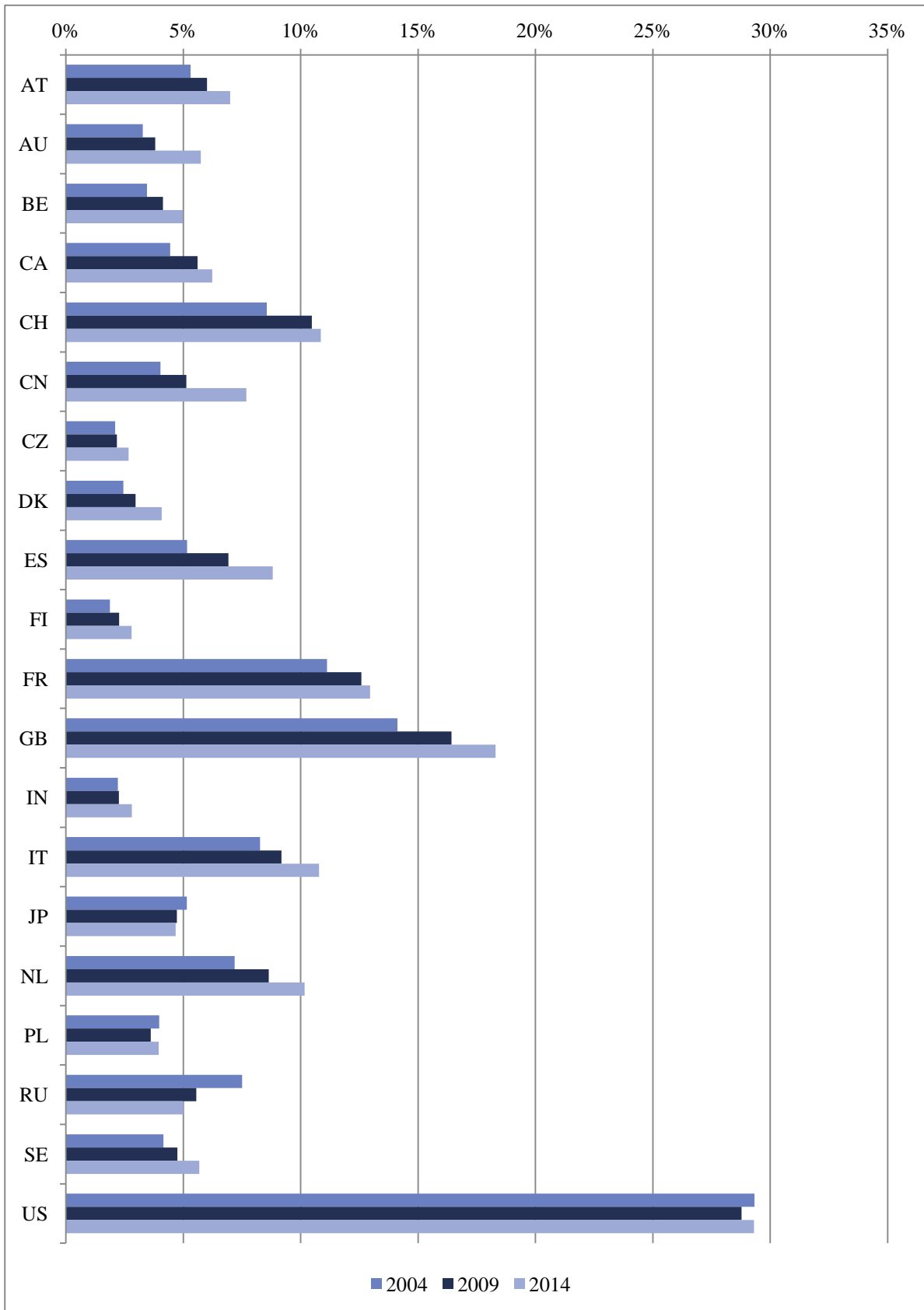
Source: Web of Science, queries and calculations by Fraunhofer ISI

4.2 Co-publication profile of Germany

The German partner countries are displayed in Figure 22. The USA are clearly ahead, followed by the United Kingdom and France. So these are mainly size effects as well as effects of strong science systems on these countries. Switzerland hosts international (research) organizations, is a direct neighbour country to Germany, also uses German as an official language and – most outstandingly – has a very strong and excellent research landscape. In consequence, Switzerland is the fourth largest collaboration partner country for Germany. Given the size of the country (about 8 million inhabitants), the absolute number of co-publications reaches an outstanding level. However, also the Netherlands (17 million inhabitants) and also Italy (60 million in habitants) also account for about 10% of Germany's international co-publications. China's contribution increased considerably in the recent years, but still just reaches a level of about 8%.

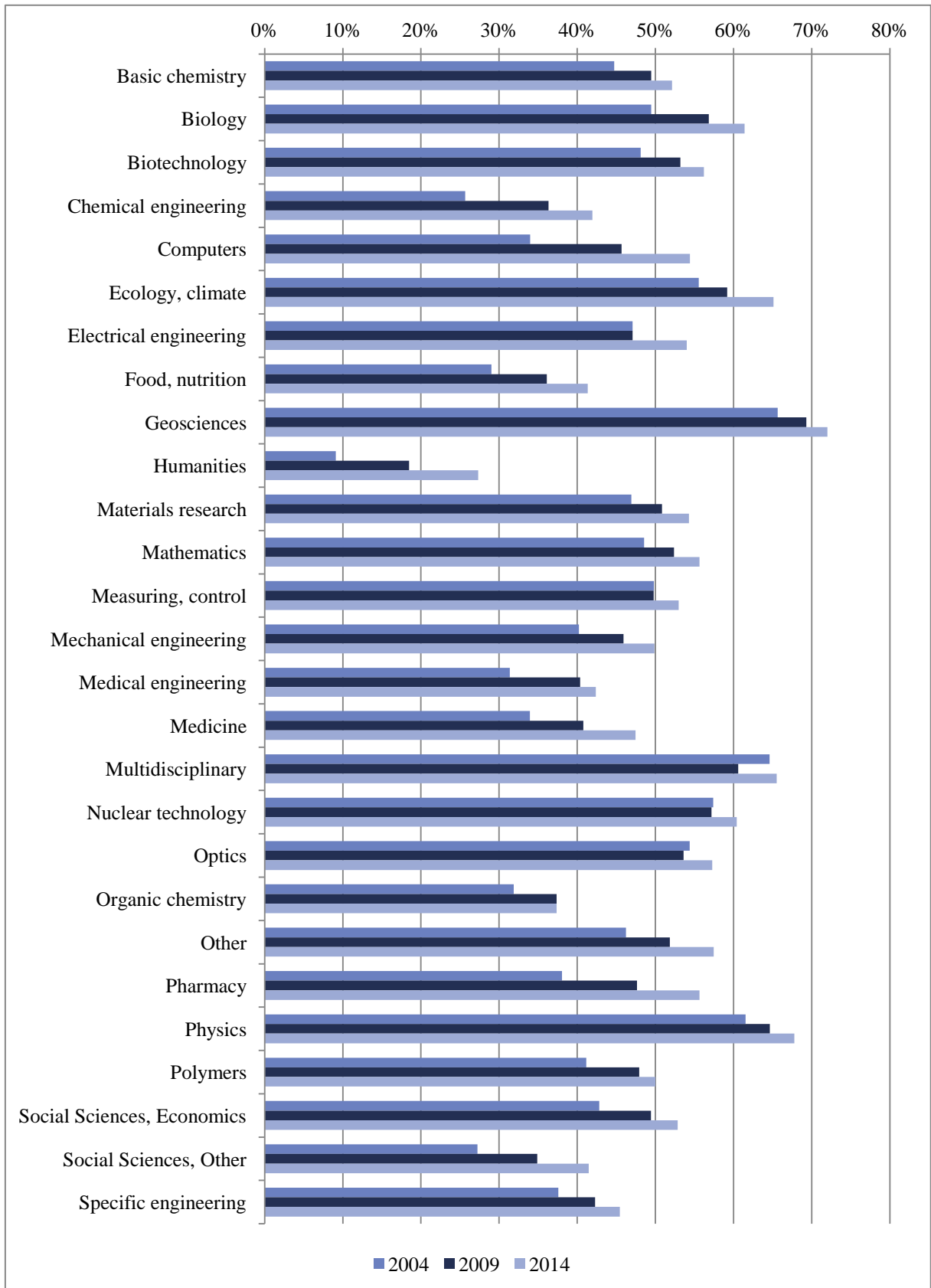
As Figure 23 shows, the international co-publications in basic research fields like physics, chemistry or biology are highest as well as fields that address global challenges and global research questions like geosciences or ecology/climate reach rather high shares of international collaboration in the German profile, while application oriented engineering fields reach a medium level and medical engineering and measuring/control as well as arts, humanities and social sciences show rather low shares compared to the German average.

Figure 22: The 20 most important co-publication countries for Germany according to whole-count numbers for the years 2004, 2009 and 2014



Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 23: Co-publication profile of Germany according to whole-count numbers for the years 2004, 2009 and 2014



Source: Web of Science, queries and calculations by Fraunhofer ISI

4.3 Co-publications between Germany and the EU

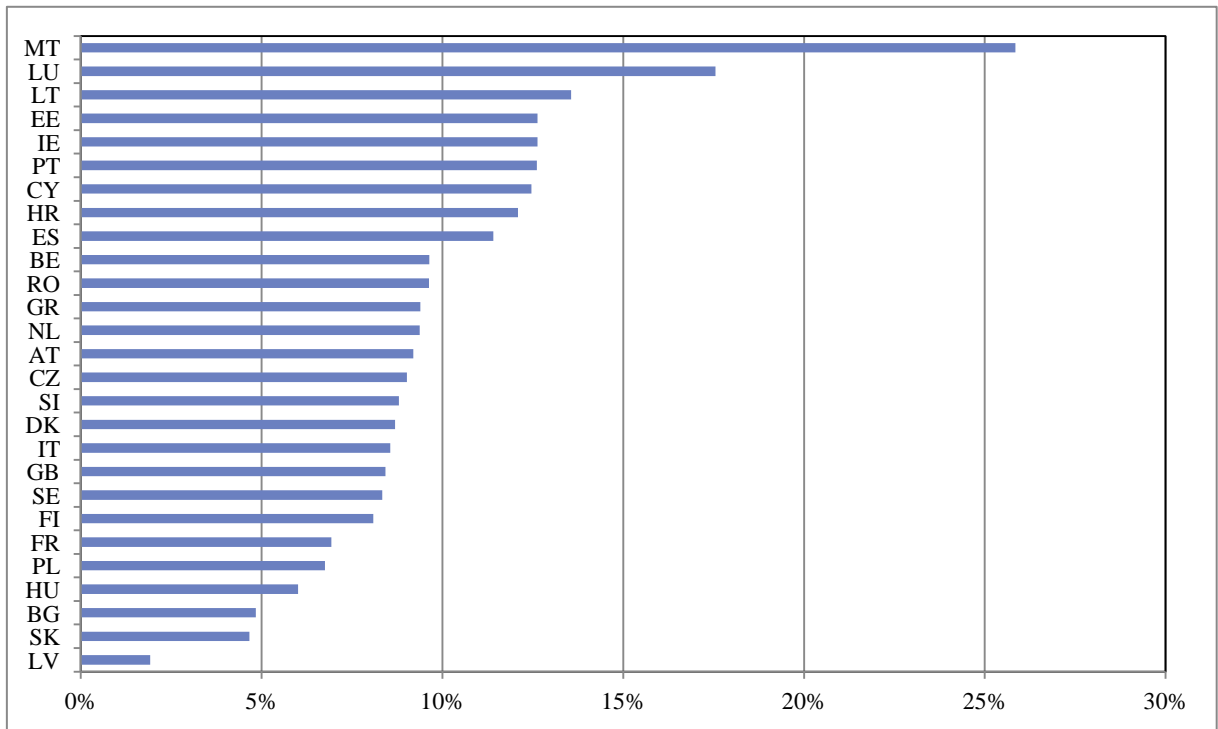
The EU member countries are important partners for German research institutions. On the one hand, the geographical and cultural distance is low. On the other hand, the European research funding – be it under the Framework Programs, the ERC or also bilateral research programs – fosters the intra-EU collaboration. The absolute numbers of collaborations of Germany with partners within the EU are highest for the largest countries – United Kingdom, France, Italy – and are rather low for the small countries as well as for the Eastern European countries. The highest growth rate since 2000, however, can be found for the smallest countries – Malta and Luxembourg – which should not be over-interpreted, but also for Baltic countries Estland and Lithuania as well as Ireland, Portugal or Spain.

Table 5: Number of international co-publications between Germany and EU countries according to whole-count numbers for the years 2001 to 2014

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
AT	1,343	1,363	1,497	1,741	1,832	1,946	2,185	2,436	2,634	3,108	3,390	3,721	3,953	4,113
BE	962	957	1,020	1,132	1,191	1,252	1,376	1,510	1,818	2,098	2,329	2,445	2,731	2,920
BG	228	229	224	282	298	314	374	327	406	374	392	416	402	380
CY	26	25	25	45	28	26	31	43	64	100	139	178	184	176
CZ	545	566	566	690	697	802	856	947	953	1,103	1,179	1,423	1,422	1,587
DK	723	748	761	803	875	1,056	1,025	1,120	1,302	1,626	1,709	2,058	2,109	2,362
EE	47	71	64	61	68	56	88	96	104	168	226	254	319	317
ES	1,179	1,335	1,387	1,690	1,891	2,135	2,396	2,592	3,035	3,508	3,882	4,590	4,778	5,143
FI	533	563	562	613	714	754	865	905	993	1,125	1,208	1,356	1,458	1,625
FR	3,050	3,241	3,396	3,648	4,118	4,175	4,612	4,800	5,531	5,946	6,310	6,770	7,303	7,572
GB	3,672	3,870	4,167	4,628	4,995	5,377	6,037	6,532	7,213	8,018	8,527	9,335	9,987	10,679
GR	371	404	447	493	470	618	661	713	887	1,010	1,160	1,389	1,337	1,401
HR	128	120	146	167	173	149	176	188	230	324	375	470	434	489
HU	513	502	557	584	622	619	679	675	703	786	931	1,077	1,094	1,141
IE	146	166	213	229	321	390	408	474	530	627	725	786	846	877
IT	2,075	2,278	2,302	2,711	2,934	3,120	3,505	3,710	4,031	4,653	4,987	5,598	6,048	6,310
LT	45	48	59	69	87	111	121	102	108	167	214	220	221	249
LU	20	26	35	39	39	47	66	82	99	133	143	162	201	231
LV	61	61	50	58	60	53	49	68	69	76	69	64	81	90
MT	1	1	4	2	5	7	12	12	11	16	19	29	24	25
NL	1,797	1,927	2,102	2,355	2,602	2,906	3,002	3,308	3,798	4,392	4,643	5,237	5,678	5,920
PL	1,044	1,044	1,203	1,307	1,308	1,389	1,408	1,436	1,585	1,669	1,801	2,096	2,215	2,330
PT	232	275	284	392	393	503	477	559	602	745	867	1,043	1,140	1,234
RO	229	248	244	261	290	313	397	374	386	411	533	762	814	786
SE	1,119	1,150	1,232	1,361	1,472	1,617	1,704	1,757	2,085	2,330	2,460	2,886	3,152	3,306
SI	129	151	146	139	170	164	186	212	275	290	374	424	409	449
SK	203	218	198	261	228	314	341	320	372	383	411	491	401	439

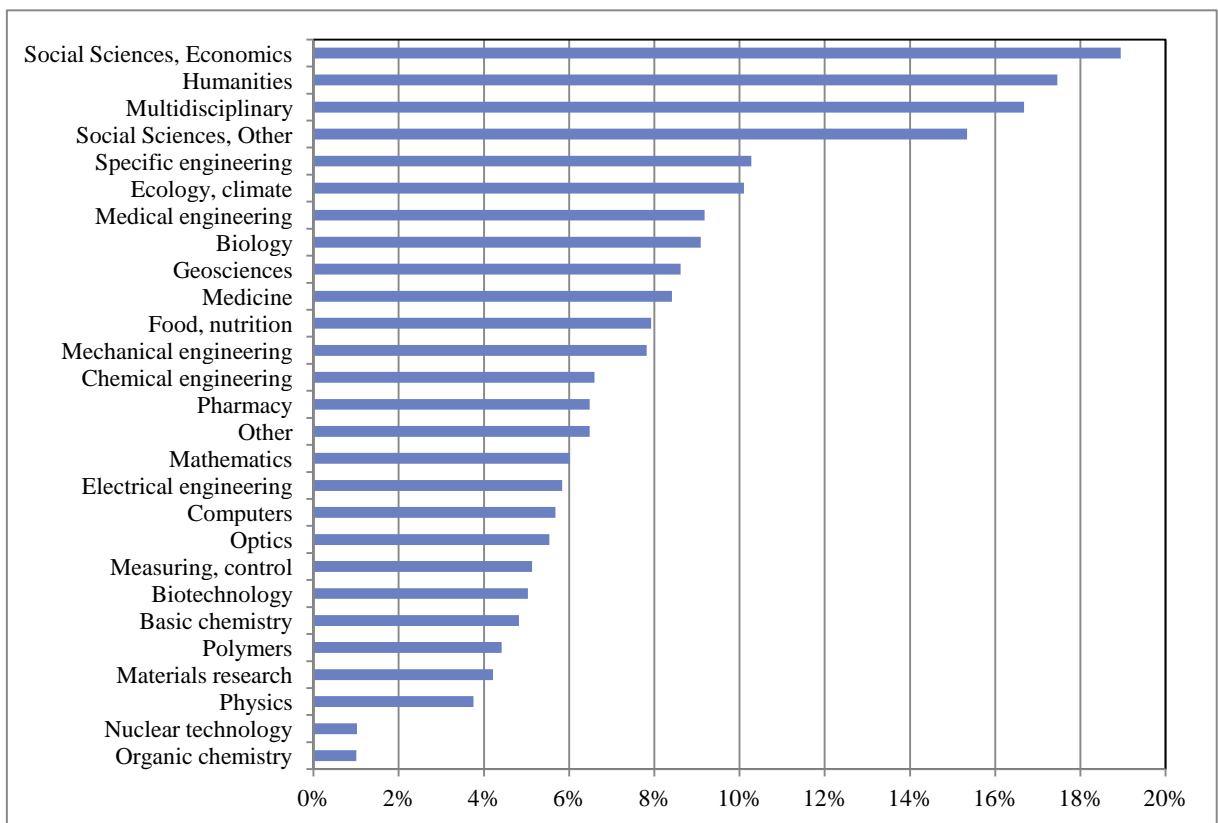
Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 24: Compound annual growth rate (CAGR) of co-publications between Germany and the respective country, 2000-2014



Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 25: Compound annual growth rate (CAGR) of co-publications between Germany and EU-28 countries in 26 fields, 2000-2014



Source: Web of Science, queries and calculations by Fraunhofer ISI

In case of scientific fields, the most important inner-European collaboration activities with publication output are Medicine, Physics, Biology and Biotechnology as well as Basic chemistry. The smallest fields are Chemical engineering and Organic chemistry, but also Food/nutrition, Polymers and Nuclear technologies are rather small scientific fields in terms of absolute numbers. The largest growth rates (see Figure 25) can be found for Social sciences (Economics and others), Humanities as well as Multidisciplinary. Also Specific engineering and Ecology/climate reach a level of 10% annual growth on average of the years 2000-2014. Nuclear technologies and organic chemistry belong to the fields of the smallest growth. In these fields the co-publications between Germany and the EU-28 countries only increased by about 1% every year since 2000.

Table 6: Co-publications between Germany and the EU in different fields according to whole-count numbers for the years 2001 to 2014

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Basic chemistry	1,525	1,512	1,596	1,829	1,812	1,909	1,973	2,077	2,376	2,460	2,583	2,650	2,723	2,878
Biology	1,214	1,277	1,271	1,422	1,534	1,779	1,949	2,008	2,173	2,619	2,729	3,225	3,541	3,588
Biotechnology	1,900	1,914	1,985	2,095	2,233	2,409	2,570	2,646	2,820	3,118	3,185	3,366	3,362	3,513
Chemical engineering	123	124	112	152	149	150	181	162	199	206	238	249	282	242
Computers	292	459	548	572	660	716	393	457	523	640	667	728	780	808
Ecology, climate	704	772	780	912	987	1,151	1,295	1,363	1,437	1,645	1,832	1,946	2,178	2,266
Electrical engineering	308	298	313	364	309	379	431	436	454	515	593	580	580	644
Food, nutrition	114	136	130	132	163	201	222	239	250	265	291	318	340	323
Geosciences	525	654	631	686	742	857	901	983	1087	1217	1177	1333	1483	1539
Humanities	39	43	64	61	79	87	119	148	181	204	259	292	332	352
Materials research	1,475	1,501	1,419	1,526	1,597	1,606	1,826	1,743	1,864	1,856	2,093	2,038	2,234	2,244
Mathematics	529	606	653	647	629	755	826	980	995	1,096	1,065	1,098	1,219	1,232
Measuring, control	393	422	517	494	487	472	491	568	556	594	576	626	716	751
Mechanical engineering	261	255	304	298	385	433	464	554	527	531	582	582	669	717
Medical engineering	289	323	335	375	385	431	501	532	550	594	643	750	770	916
Medicine	3,417	3,617	3,969	4,336	4,857	5,240	5,897	6,345	7,016	7,756	7,944	8,627	9,199	9,646
Multidisciplinary	185	197	197	231	289	302	358	480	444	678	885	1,332	1,667	1,768
Nuclear technology	377	370	417	354	417	313	416	326	466	294	512	233	466	341
Optics	292	299	288	317	465	433	486	446	541	592	564	608	640	661
Organic chemistry	206	175	202	210	217	251	243	239	257	250	261	294	263	214
Other	256	295	319	335	366	426	462	459	560	555	599	592	681	725
Pharmacy	410	375	410	440	556	534	555	577	668	691	761	862	841	848
Physics	4,651	4,880	4,960	5,396	5,439	5,670	5,792	5,878	6,224	6,683	6,907	7,145	7,527	7,358
Polymers	274	189	248	225	207	218	191	247	271	251	349	341	349	326
Social Sciences, Economics	104	112	157	187	215	240	304	452	521	593	657	694	800	919
Social Sciences, Other	262	262	310	381	406	464	561	725	865	1,005	1,146	1,227	1,419	1,549
Specific engineering	172	166	211	215	293	235	342	296	421	393	599	505	736	692

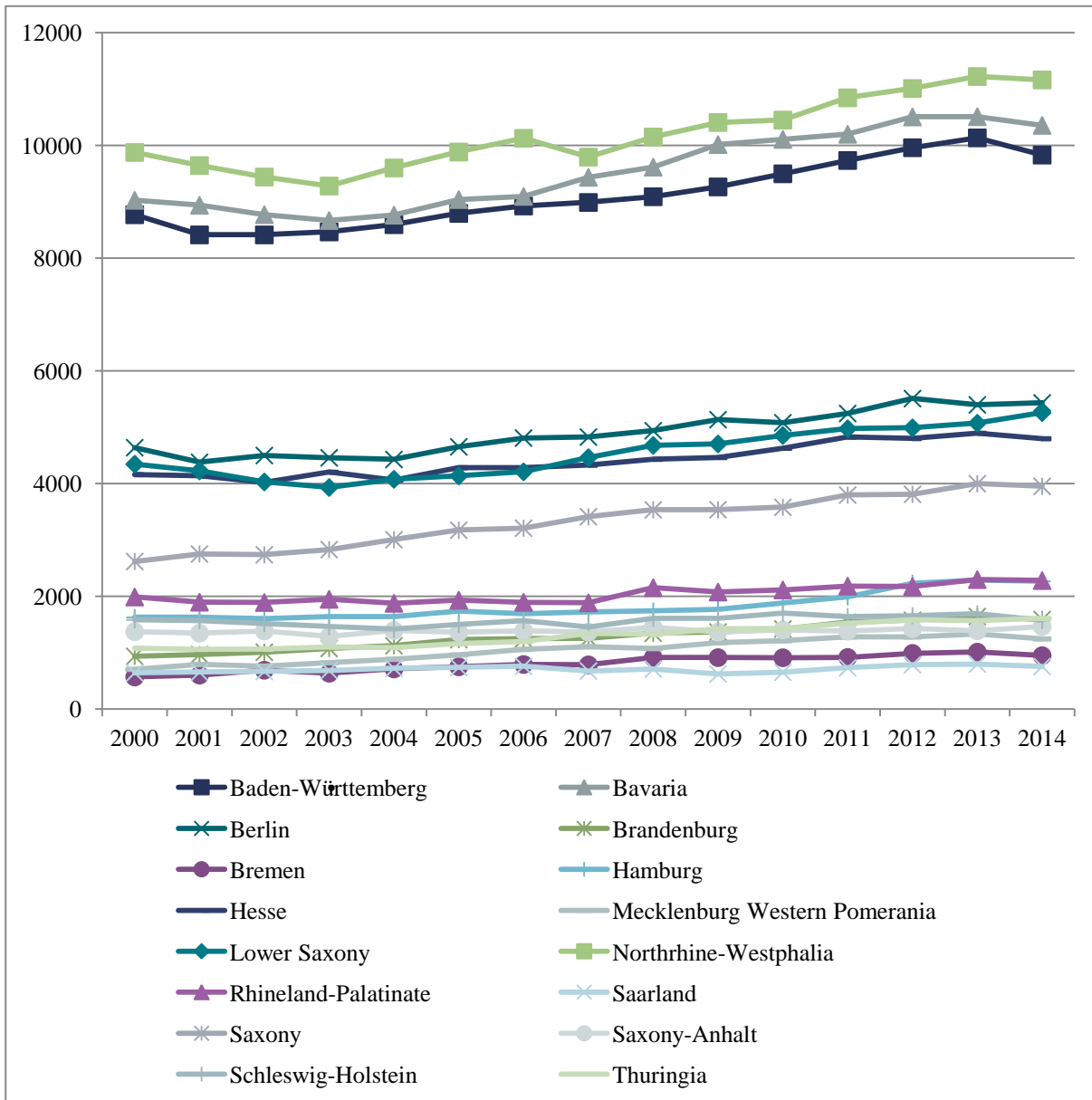
Source: Web of Science, queries and calculations by Fraunhofer ISI

5 Regional analysis of Germany

Germany is a federal state with 16 federal regions – called Bundesländer. In terms of the European Nomenclature of regions (NUTS) this is the NUTS1-level. The Bundesländer are a political and administrative level, mainly responsible for inner security (police) and for education. The central government in Berlin, on the other hand, has limited responsibilities in these matters. The Bundesländer are also responsible for the universities in their region and therefore also for academic research in Germany. In addition, the non-university research organizations are also co-funded by the Bundesländer. In the case of Helmholtz and Fraunhofer, the central government covers 90% of the budgets and the Bundesländer cover 10% of the institutes located in their region. In the case of Max-Planck and Leibniz, the shares of the institutional funding are 50:50. All this means that the public research is heavily influenced by the political and budgetary constraints of the individual Bundesländer, resulting in different factor endowments and financial situations, which might influence also the output of academic research. In this chapter of this report, we briefly analyse the differences in the publication outputs of the Bundesländer and their scientific performance in terms of citations.

The absolute publication numbers for the 16 German regions are depicted in Figure 26. Northrhine-Westphalia, Bavaria and Baden-Württemberg are with around 10,000 publications in 2014 the regions with most publications while Berlin, Lower Saxony, Hesse and Saxony register between 4000 and 6000 publications in 2014.

Figure 26: Publication numbers of the German regions in the SCIE and the SSCI (fractional counting) for the years 2000-2014



Source: Web of Science, queries and calculations by Fraunhofer ISI

To preclude size effects, these absolute numbers were normalized with the number of inhabitants of the regions (Table 7). In that case, Berlin, Bremen and Hamburg have the highest number of publications while Rhineland-Palatinate and Schleswig-Holstein show the lowest number of publications per 1 million inhabitants.

Table 7: Number of publications per 1 million inhabitants of the German regions in the SCIE and the SSCI according to fractional counting

Region	2005	2006	2007	2008	2009	2010	2012	2013	2014
Baden-Württemberg	821	831	837	846	862	884	929	947	959
Bavaria	726	730	755	768	800	808	824	844	839
Berlin	1,373	1,417	1,418	1,446	1,497	1,476	1,600	1,656	1,599
Brandenburg	481	488	493	531	542	566	627	643	671
Bremen	1,134	1,195	1,185	1,380	1,382	1,379	1,409	1,517	1,545
Hamburg	1,001	970	981	984	1,000	1,060	1,168	1,300	1,321
Hesse	702	703	712	730	736	764	809	801	813
Mecklenburg Western Pomerania	559	620	654	640	709	734	794	797	833
Lower Saxony	517	527	559	587	592	612	640	642	652
Northrhine-Westphalia	547	561	543	564	580	585	618	628	639
Rhineland Palatinate	476	467	466	533	516	527	547	545	576
Saarland	701	725	649	687	607	641	733	791	804
Saxony	739	751	803	838	844	859	934	940	988
Saxony-Anhalt	547	562	560	601	575	597	603	627	616
Schleswig Holstein	531	554	513	567	568	601	587	592	603
Thuringia	493	513	580	579	628	635	693	725	723

Source: Web of Science, Eurostat, queries and calculations by Fraunhofer ISI

Given the publication output of the individual regions, their share in German and worldwide publications can be calculated (Table 8 and Table 9). The shares of the regions in respect to Germany vary between 1.0% and 15.5%. The shares are mostly stable for the observation period. For some regions with a lower publication output, for example Brandenburg, Hamburg and Thuringia, the shares increased slightly, while for some regions with a higher publication output, for example Northrhine-Westphalia, Baden-Württemberg and Bavaria, the shares decreased slightly. However, a shift between the regions is not yet observable.

When measured by the worldwide publication output, the maximum share amounts to 0.7% for both North-Rhine-Westphalia and Bavaria (Table 9). Again, the shares are mostly stable for the observation period, showing that the relative weight in all publications in the scientific landscape has remained the same.

Table 8: Share of the German regions on national publications in the SCIE and the SSCI according to fractional counting

Region	2006	2007	2008	2009	2010	2011	2012	2013	2014
Baden-Württemberg	14.9%	14.8%	14.4%	14.3%	14.3%	14.2%	14.1%	14.0%	13.6%
Bavaria	15.2%	15.6%	15.2%	15.5%	15.2%	14.9%	14.9%	14.5%	14.3%
Berlin	8.0%	8.0%	7.8%	7.9%	7.7%	7.7%	7.8%	7.4%	7.5%
Brandenburg	2.1%	2.1%	2.1%	2.1%	2.1%	2.3%	2.2%	2.3%	2.2%
Bremen	1.3%	1.3%	1.5%	1.4%	1.4%	1.3%	1.4%	1.4%	1.3%
Hamburg	2.8%	2.8%	2.8%	2.7%	2.8%	2.9%	3.2%	3.2%	3.1%
Hesse	7.2%	7.1%	7.0%	6.9%	7.0%	7.0%	6.8%	6.7%	6.6%
Mecklenburg Western Pomerania	1.8%	1.8%	1.7%	1.8%	1.8%	1.9%	1.8%	1.8%	1.7%
Lower Saxony	7.0%	7.4%	7.4%	7.3%	7.3%	7.3%	7.1%	7.0%	7.3%
Northrhine-Westphalia	16.9%	16.2%	16.1%	16.1%	15.8%	15.8%	15.6%	15.5%	15.5%
Rhineland Palatinate	3.2%	3.1%	3.4%	3.2%	3.2%	3.2%	3.1%	3.2%	3.2%
Saarland	1.3%	1.1%	1.1%	1.0%	1.0%	1.1%	1.1%	1.1%	1.0%
Saxony	5.4%	5.6%	5.6%	5.5%	5.4%	5.5%	5.4%	5.5%	5.5%
Saxony-Anhalt	2.3%	2.3%	2.3%	2.1%	2.1%	2.0%	2.0%	1.9%	2.0%
Schleswig Holstein	2.6%	2.4%	2.6%	2.5%	2.6%	2.4%	2.3%	2.3%	2.2%
Thuringia	2.0%	2.2%	2.1%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%

Source: Web of Science, queries and calculations by Fraunhofer ISI

Table 9: Share of the German regions on worldwide publications in the SCIE and the SSCI according to fractional counting

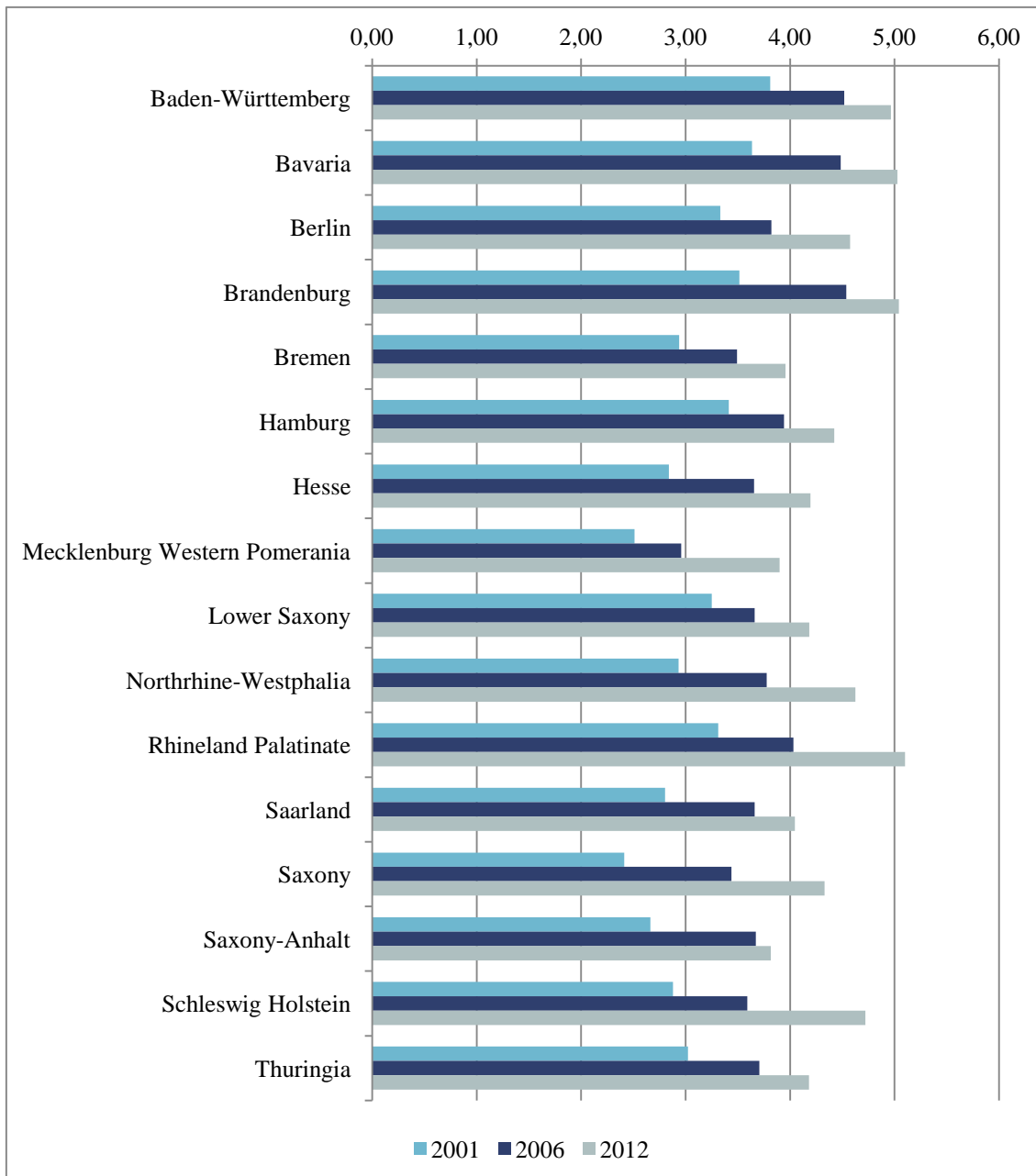
Region	2006	2007	2008	2009	2010	2011	2012	2013	2014
Baden-Württemberg	0.9%	0.8%	0.8%	0.8%	0.8%	0.7%	0.7%	0.7%	0.6%
Bavaria	0.9%	0.9%	0.8%	0.8%	0.8%	0.8%	0.8%	0.7%	0.7%
Berlin	0.5%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
Brandenburg	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Bremen	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Hamburg	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.1%
Hesse	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.3%	0.3%	0.3%
Mecklenburg Western Pomerania	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Lower Saxony	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.3%	0.3%
Northrhine-Westphalia	1.0%	0.9%	0.9%	0.9%	0.8%	0.8%	0.8%	0.8%	0.7%
Rhineland Palatinate	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Saarland	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Saxony	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Saxony-Anhalt	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Schleswig Holstein	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Thuringia	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%

Source: Web of Science, queries and calculations by Fraunhofer ISI

In contrast to the distribution of the publication output, also regions with a lower publication output excel in the citation rate (Figure 27). Bavaria and Baden-Württemberg, both regions

with a high publication output, as well as Brandenburg and Rhineland-Palatinate, regions with a relatively low publication output, show very high citation rates of about 5 citations per publication. Mecklenburg Western Pomerania and Saarland register with less than 4 citations per publication the lowest citation rate. While all regions increased their citation rates over the years, Saxony has shown the highest increase from 2.4 citations per publication in 2001 to 4.3 citations per publication in 2012.

Figure 27: Observed citation rate of the German regions in the SCIE and the SSCI (fractional counting) for the years 2001, 2006 and 2012

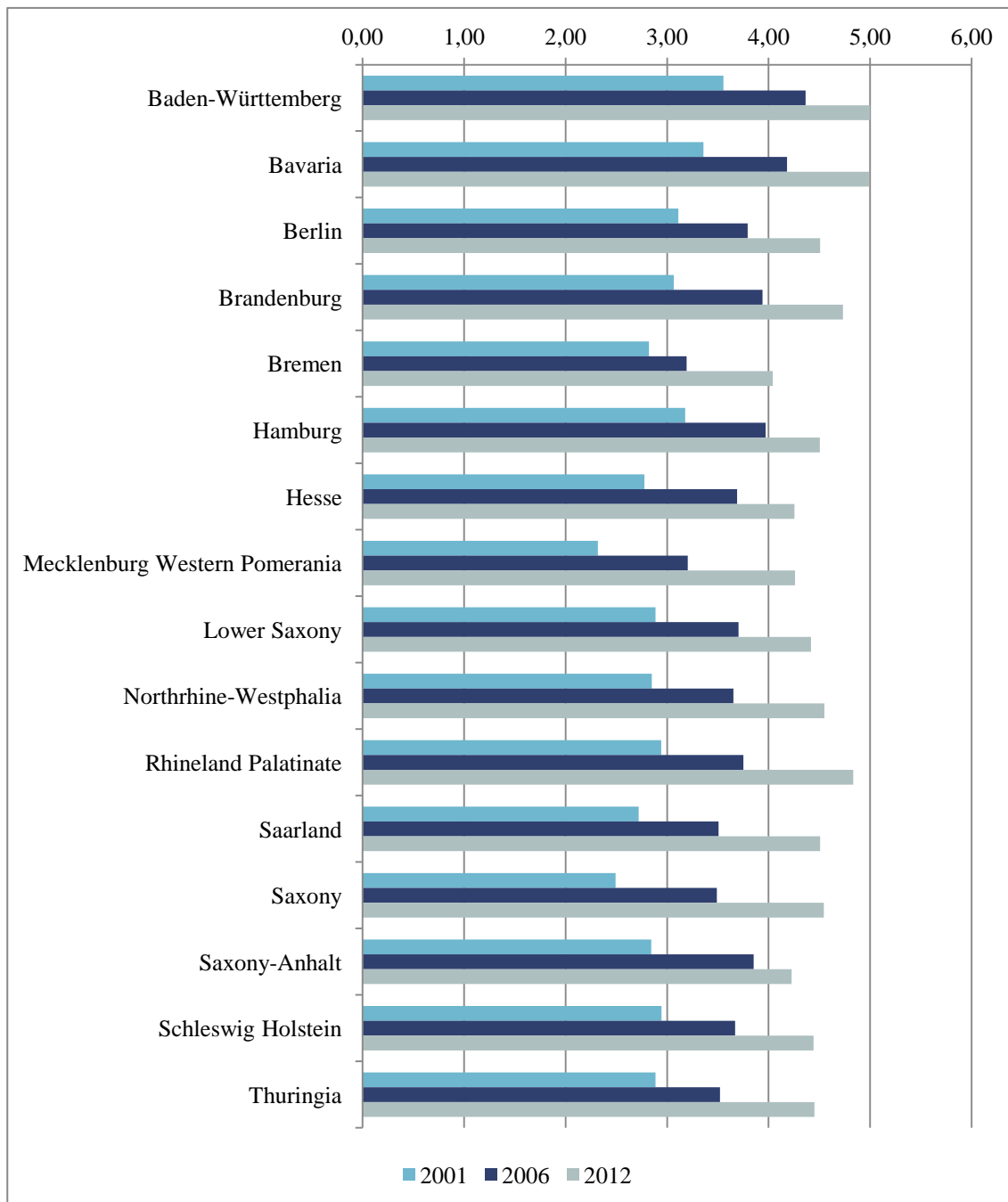


Source: Web of Science, queries and calculations by Fraunhofer ISI

The expected citations show the average citation rate in the fields used for publication (Figure 28). The interdependency between the expected and the observed citation rate can be seen in

the comparison of Figure 27 and Figure 28; publications in fields with a high/low expected citation rate can influence the citation rate positively/negatively. There are some exceptions to that rule in that way that regions gain fewer or more citations than the average in the field. In particular, Lower Saxony, Thuringia, Mecklenburg Western Pomerania, Saarland and Saxony-Anhalt gain fewer citations than other publications in the respective fields. However, Brandenburg, Schleswig-Holstein and Rhineland Palatinate acquire more citations than similar publications.

Figure 28: Expected citation rate of the German regions in the SCIE and the SSCI (fractional counting) for the years 2001, 2006 and 2012



Source: Web of Science, queries and calculations by Fraunhofer ISI

6 Publications from German universities and non-university research institutions

The German research landscape is differentiated following a mission orientation. While the large number of German universities is responsible for both, research and education, the large public research organizations (PROs), namely Max-Planck, Fraunhofer, Helmholtz and Leibniz, usually only conduct research. Their teaching obligations are restricted and mainly result from co-affiliations or individual career paths. However, the role in doctoral students' education is considerable. Many research institutes employ doctoral students and these students considerably contribute to the publication output of the research institutes. It needs to be stressed that in Germany, students can only graduate from universities and not from research institutes. Only the universities have the right to grant a PhD diploma. Consequently, all doctoral students at PROs are also somehow affiliated to a university.

The PROs have very different missions, which can, first of all, be characterized by basic research (Max Planck) and applied research (Fraunhofer). In addition, several missions like energy and large-scale research (Helmholtz) occur. Both, the Helmholtz Association and the Leibniz Association, conduct applied as well as basic research. The Helmholtz Association developed its profile in medical research, running medical centers in collaboration with universities, in different locations in Germany. The Leibniz Association covers research at museums and also several particular topics (e.g. marine research), but also a number of institutes of the social sciences.

These are very different conditions for a comparison of the publication output of the universities and the public research organizations. In the following, we will dig deeper into this topic to provide a more complete picture of the publication activities of universities and PROs besides mere publication counts.

6.1 Number and share of publications

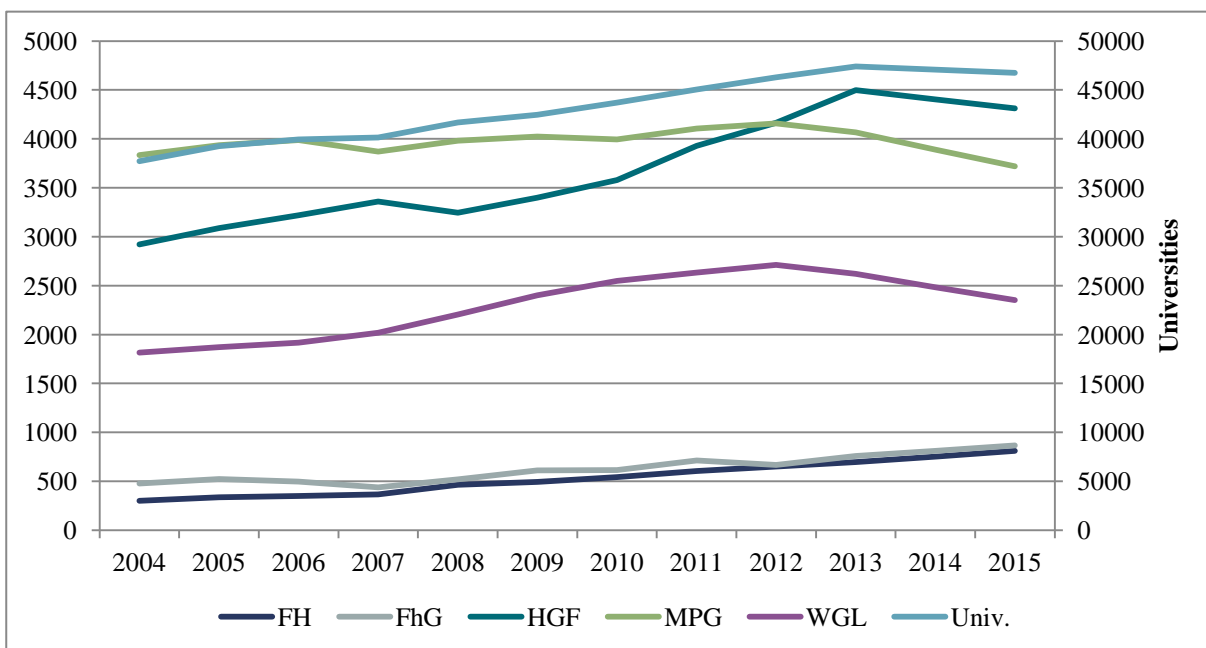
The absolute number of publications from universities and public research institutes is depicted in Figure 29. As we can see from the figure, universities by far have the largest publication output in absolute terms, although the numbers have been slightly decreasing after 2013. Among the PROs, the Helmholtz Association (HGF) has the largest publication output with about 4,300 publications in 2015. Yet, also here we can observe a slight decline in publication figures since 2013, after a period of growth in the last decade (which can be found for all PROs and the universities). With about 4000 publications in 2015, the Max Planck Society (MPG) is the second largest PRO when it comes to publication output. Here, we also observe a slight decline between 2012 in 2014, while the figure stopped growing again in 2015. Similar effects can be observed for the Leibniz Association (WGL), which scores third in absolute publication counts. The smallest public research organization in terms of publications is the

Fraunhofer Society (FHG), with about 830 journal publications in 2015 closely followed by the "Fachhochschulen" in Germany.

In Figure 30, the shares of publications of German universities and PROs in all German publications are displayed. As we can see from the figure, the shares of universities as well as the Max-Planck Society declined over the years, while the shares of the WGL and especially the HGF have risen. In addition, also the shares of the Fraunhofer Society as well as the "Fachhochschulen" have increased.

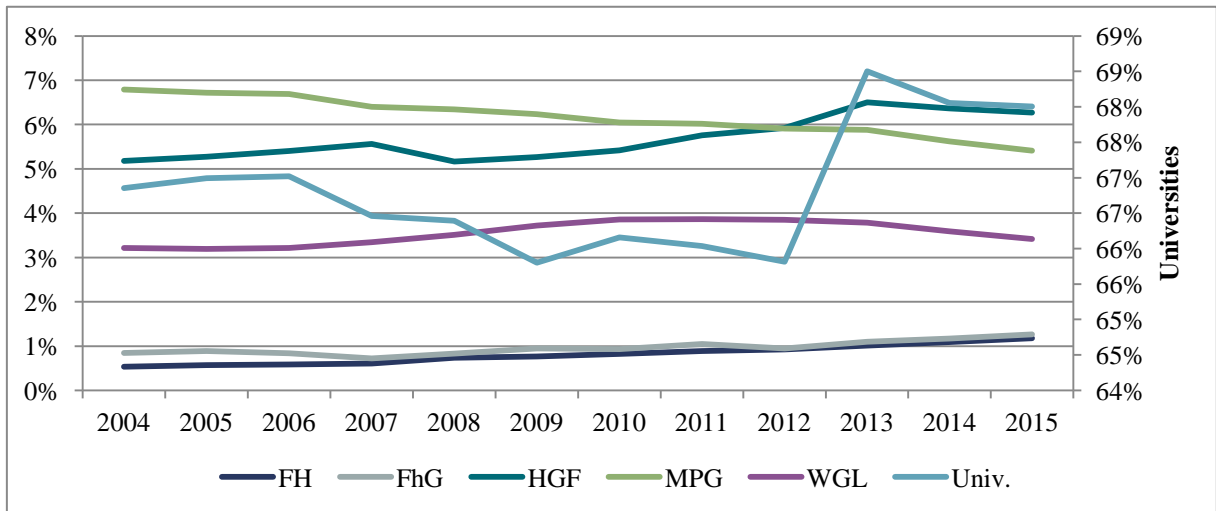
What is even more interesting, however, are the publication intensities of the universities and PROs, i.e. the number of publications per FTE researcher. As Figure 31 shows, the largest publication output per FTE researcher is achieved by Max Planck. Each researcher – on average – publishes 0.6 papers per year, with a decreasing trend in the recent years. It has to be mentioned here that the absolute number of researchers does not take into account the large number of scholarships and external visitors. This group, however, is taken into account in the case of publication output, if they put their Max Planck affiliation on the paper. This also holds for all the other PROs and also the universities, but the effect is largest in case of Max Planck due to large numbers of external and visiting scholars.

Figure 29: Number of publications of German Universities and non-university research institutions for the period 2004-2015



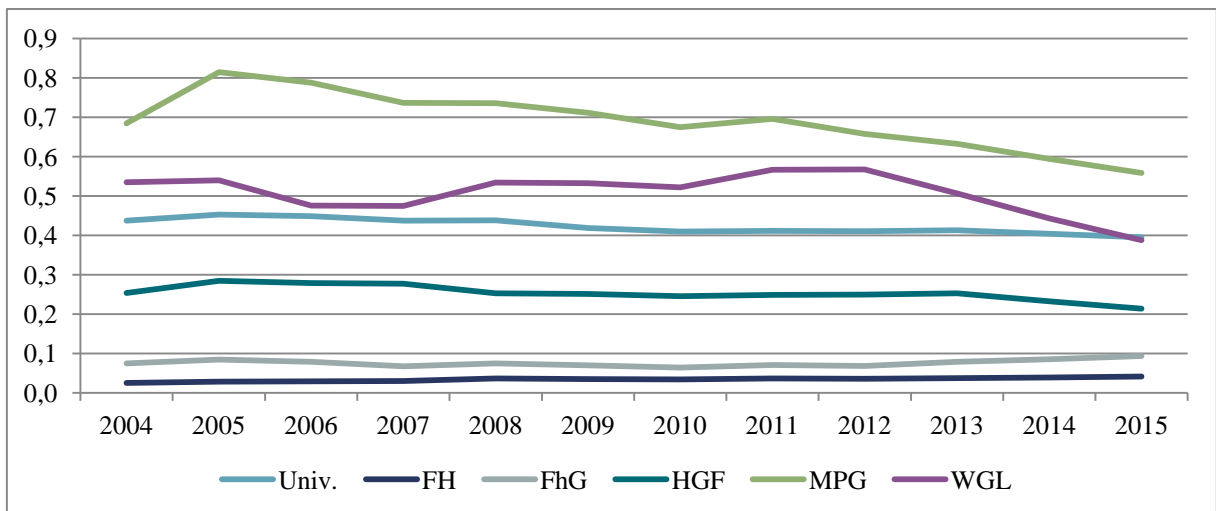
Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 30: Share of publications of German Universities and non-university research institutions for the period 2004-2015



Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 31: Number of publications per FTE of German Universities and non-university research institutions for the period 2004-2013

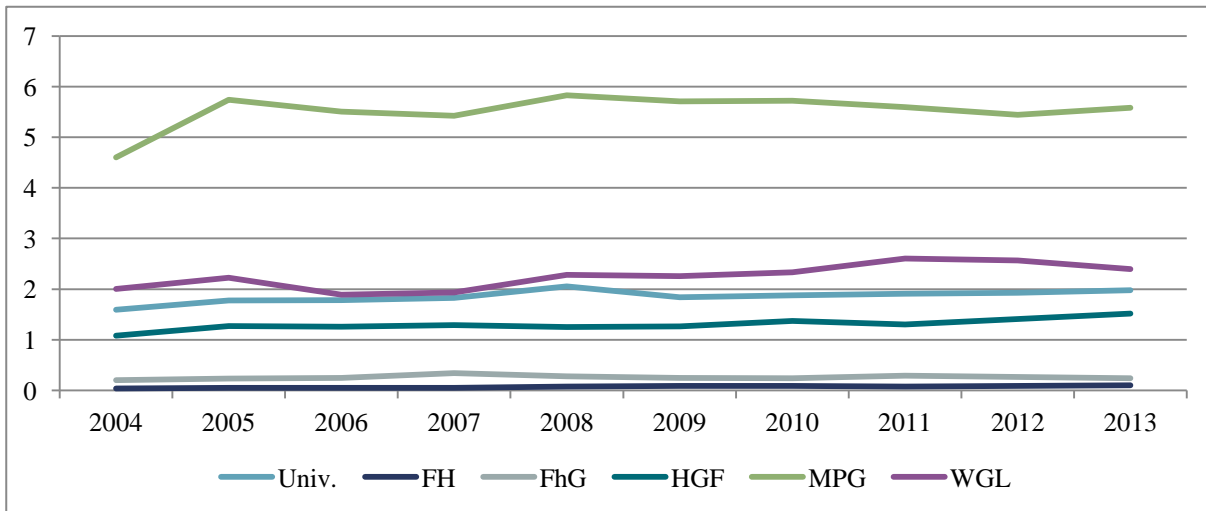


Source: Web of Science, queries and calculations by Fraunhofer ISI

In the Leibniz Association each researcher published about 0.45 papers per year, also with a decreasing trend since 2012. The other groups are rather stable in their publication output. A researcher at a German university published about 0.4 papers per year and at Helmholtz it is about 0.22 papers. The lowest publication intensity can be found in Fraunhofer (0.10 papers) and in the universities of applied sciences (0.05 papers).

As Figure 32 shows, Max Planck also receives the most citations per FTE – more than 5 citations per researcher. Researchers from the Leibniz Association receive about 2.5 citations and researchers from universities about 2 citations. Helmholtz reaches a value of 1.4, Fraunhofer of about 0.3 and the universities of applied sciences of about 0.1.

Figure 32: Number of citations per FTE of German universities and non-university research institutions for the period 2004-2013



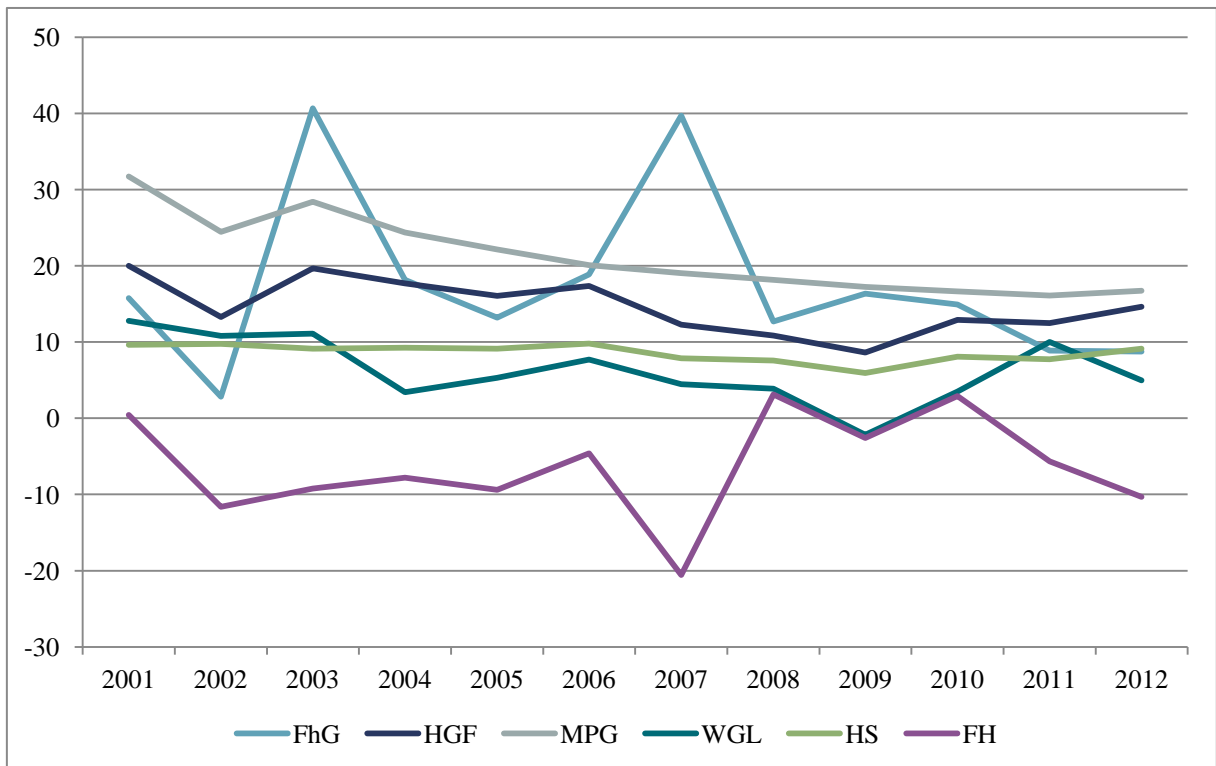
Source: Web of Science, queries and calculations by Fraunhofer ISI

6.2 Journal-specific Scientific Regard (SR), International Alignment (IA) and Excellence Rate

Within this section, we will take a closer look at the scientific regard and international alignment values of the universities and PROs. As already discussed above, the SR and the IA put the observed citation rate in perspective with the reputation of the publishing journals. The IA thereby shows whether a country publishes in more or less cited journals (compared with the world average), the SR relates the citation rate of a publication to the average citation rate in the given journal and indexes the average for all publications. Furthermore, we take a closer look at the excellence rate of the universities and PROs, i.e. the share of publications belonging to the 10% top cited publications worldwide.

The SR values of the German universities and PROs are depicted in Figure 33. Between 2001 and 2007, the SR values of nearly all research institutions have slightly declined. Since 2008 however, slight growth can be observed especially for the HGF and the WGL, while other, like Fraunhofer and the "Fachhochschulen" declined. In sum, the largest SR values can be found for the MPG, followed by the HGF, the universities and Fraunhofer. The WGL, scores fifth, however only closely behind the universities and Fraunhofer. The lowest values can be found for the "Fachhochschulen". These figures imply that publications from the MPG are the most highly cited compared to the journal average.

Figure 33: Index of the journal-specific Scientific Regard (SR) for German Universities and non-university research institutions in the SCIE and the SSCIE according to fractional counting



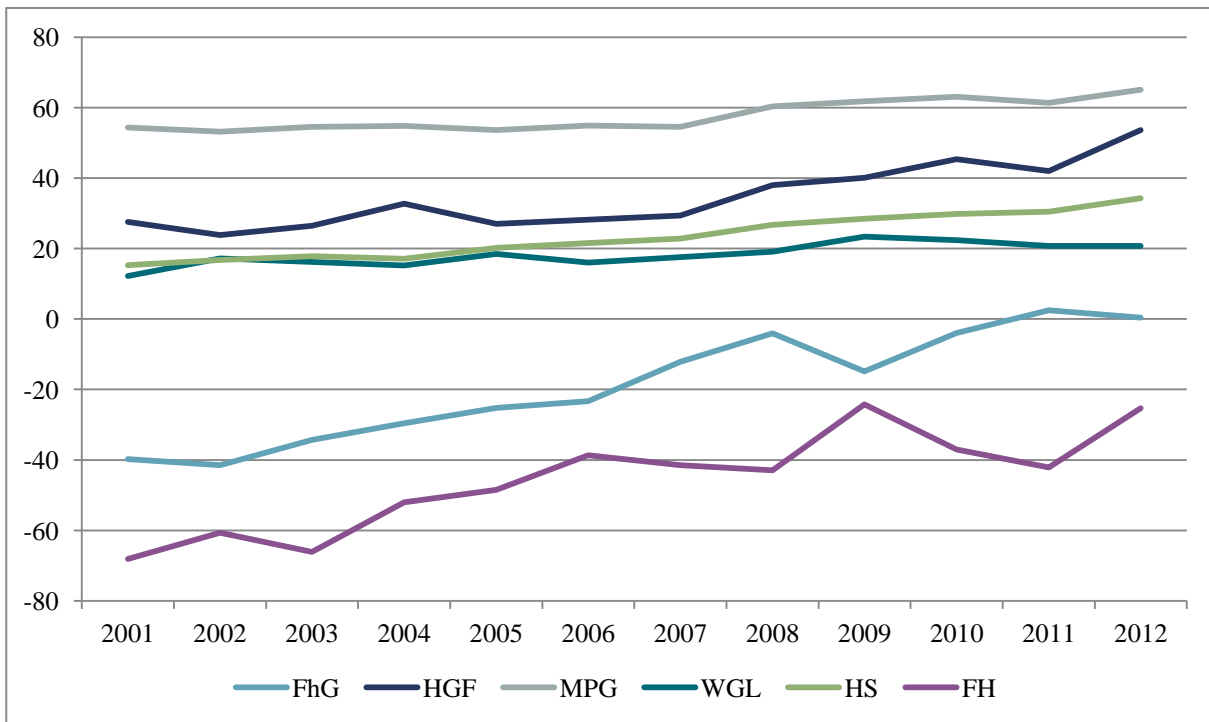
Source: Web of Science, queries and calculations by Fraunhofer ISI

To put this in perspective, Figure 34 shows the international alignment values for the universities and the PROs. As can be seen from the figure, the IA values have increased over the whole time period for basically all of the analyzed institutions. German research organizations thus increasingly publish in more highly cited and internationally visible journals. Also in this comparison, the MPG shows the largest values, followed by the HGF and the universities. Although Fraunhofer only scores fifth after the WGL, the largest growth rates can be observed for Fraunhofer.

A look at the excellence rate, once again reveals a similar picture (Figure 35). The MPG is in the lead, with about 22% of the publications being among the top 10% cited publications in the world. It is followed by the HGF, which still reaches a value of 16%. The universities scored third with a value of 12%, although this is an effect of the decline in the excellence rate for the WGL between 2011 and 2012.

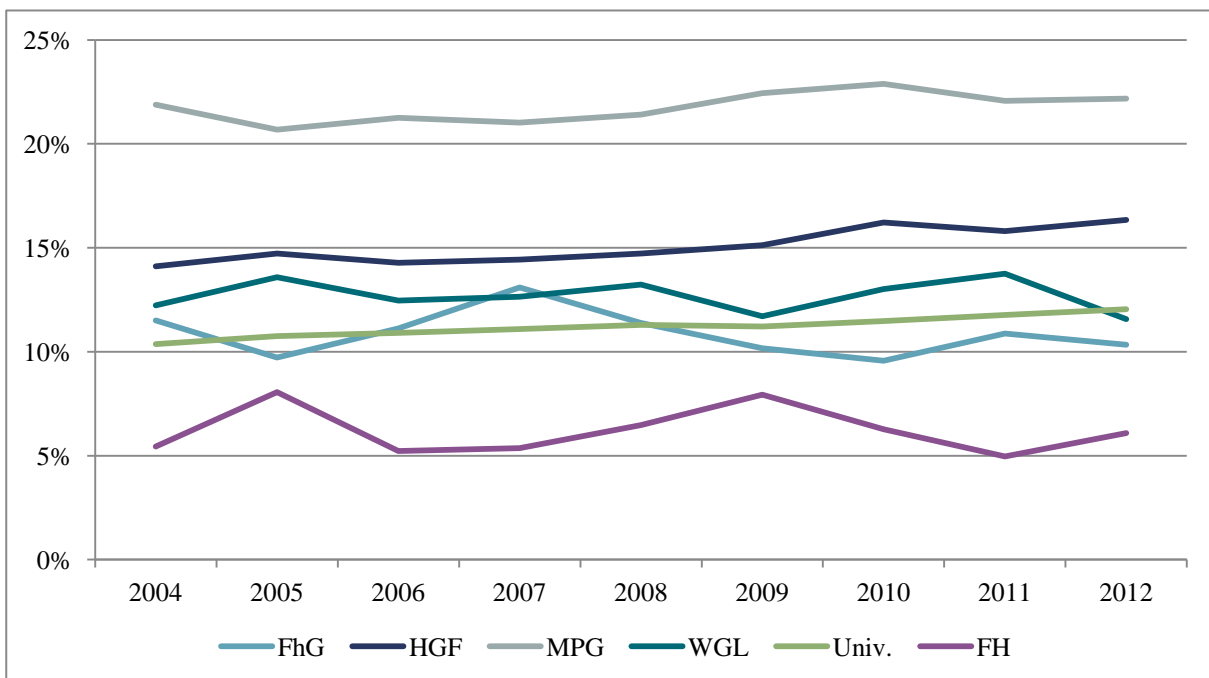
In sum, we can state that the PROs that are more focused on basic research like the MPG and the HGF score higher in scientific regard, international alignment and in scientific excellence. The more application oriented Fraunhofer Society reaches lower values within this comparison.

Figure 34: Index of the International Alignment (IA) for German Universities and non-university research institutions in the SCIE and the SSCI according to fractional counting



Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 35: Excellence Rate for German Universities and non-university research institutions countries according to fractional counting for the years 2001 to 2013



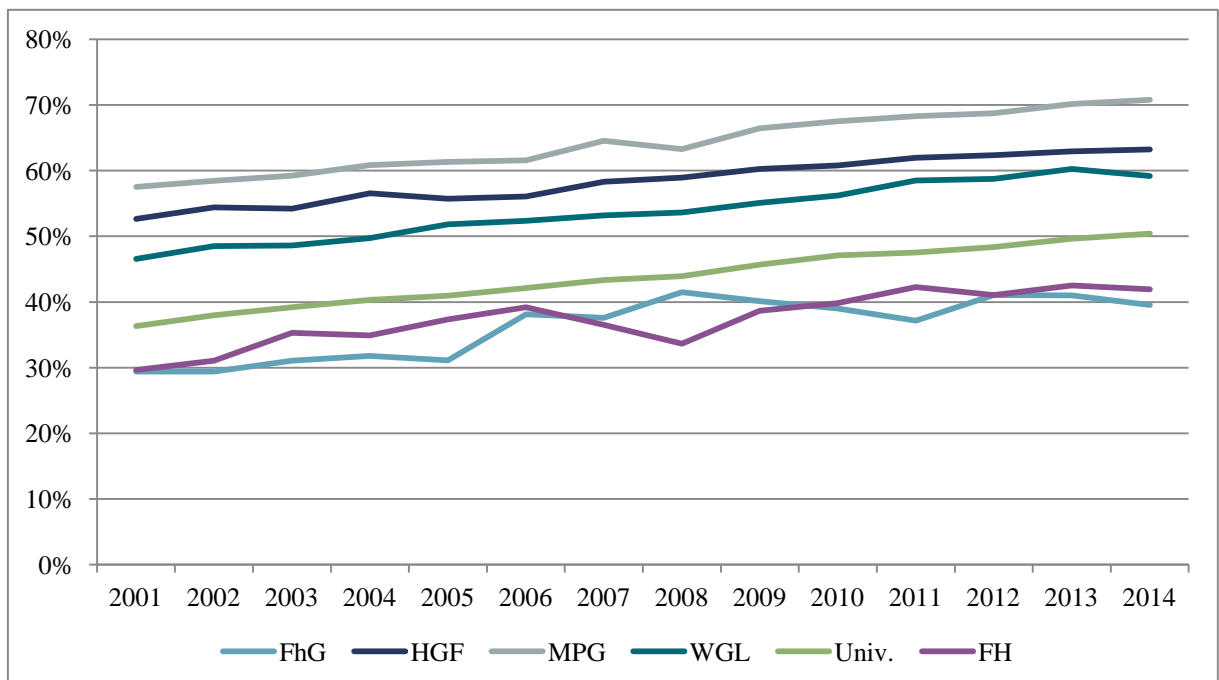
Source: Web of Science, queries and calculations by Fraunhofer ISI

6.3 Co-Publication Analysis

In this section, the international co-publication trends of universities and PROs will be described. The shares of international co-publications for the German universities and PROs in total publications of the respective institutions for the time period from 2001 to 2014 is depicted in Figure 36. It can be observed that this share is increasing over the years for all German institutions, implying that international collaboration has gained increased importance over the years. The largest shares of international co-publications can be observed for the MPG, followed by the HGF and the WGL. The universities score below these three PROs with a value of about 50% in 2014. Fraunhofer and the "Fachhochschulen" have the smallest shares of co-publications in comparison.

When looking at the co-publications between the universities and PROs, i.e. an indicator that shows how strongly the universities and PROs interact within Germany, it can clearly be found that also these number have increased over the years (Table 10), implying that also cooperation across the universities and PROs have gained importance. The most important partner for all the PROs are the universities, although cooperation activities across all of the PROs can be observed.

Figure 36: Share of international co-publications for German Universities and non-university research institutions according to whole-count numbers for the years 2001 to 2014



Source: Web of Science, queries and calculations by Fraunhofer ISI

Table 10: Co-publications between German Universities and non-university research institutions according to whole-count numbers for the years 2004, 2009 and 2014

Co-publications 2004	FhG	HGF	MPG	WGL	Univ.	FH
FhG		22	19	45	268	8
HGF	22		598	206	2,250	41
MPG	19	598		186	2,173	6
WGL	45	206	186		1,321	10
Universities	268	2,250	2,173	1,321		188
FH	8	41	6	10	188	

Co-publications 2009	FhG	HGF	MPG	WGL	Univ.	FH
FhG		40	34	34	580	19
HGF	40		859	369	3,833	78
MPG	34	859		317	3,140	23
WGL	34	369	317		2,383	41
Universities	580	3,833	3,140	2,383		431
FH	19	78	23	41	431	

Co-publications 2014	FhG	HGF	MPG	WGL	Univ.	FH
FhG		111	75	44	977	58
HGF	111		1,153	526	7,025	143
MPG	75	1,153		330	4,277	54
WGL	44	526	330		3,302	58
Universities	977	7,025	4,277	3,302		838
FH	58	143	54	58	838	

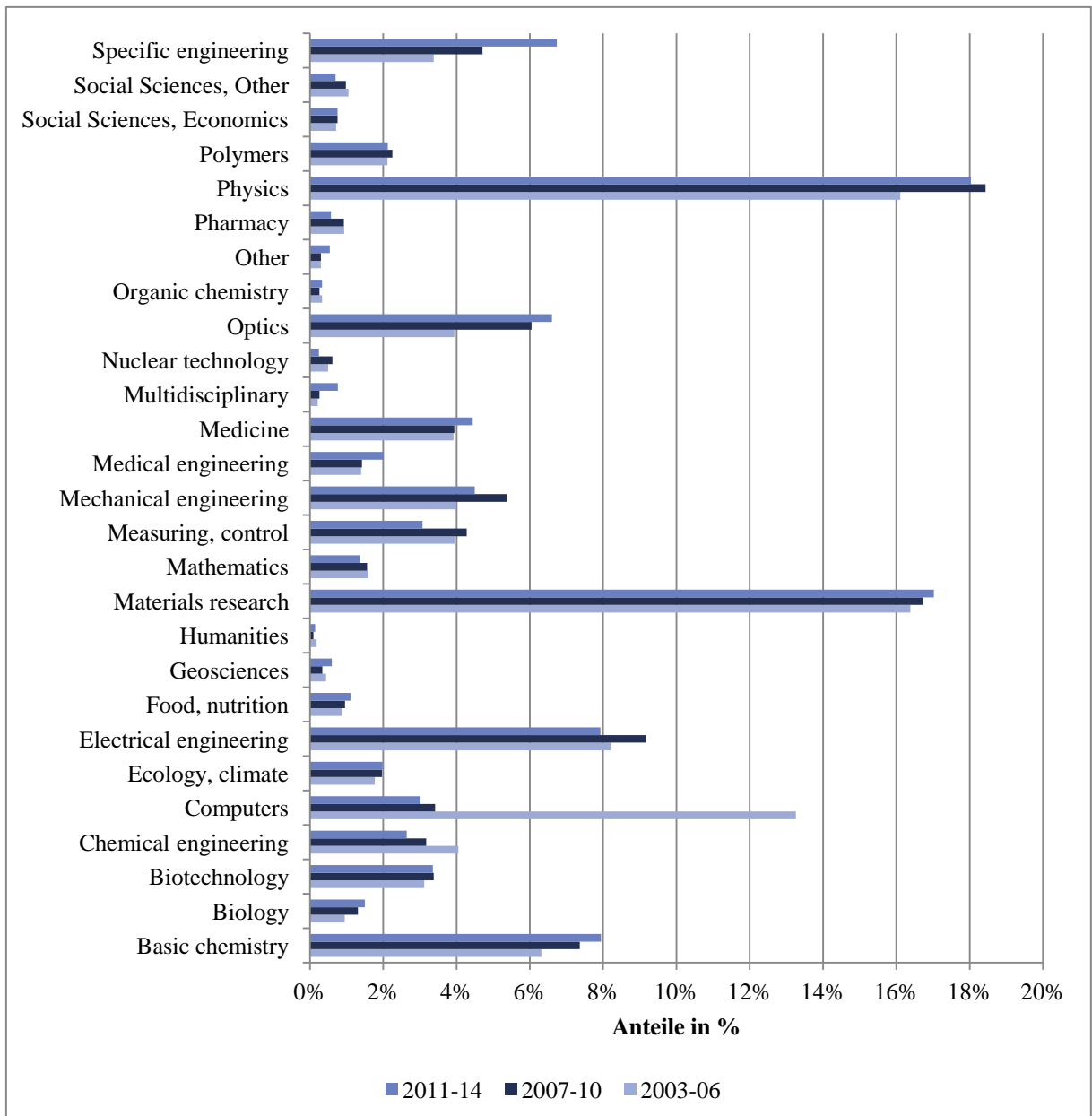
Source: Web of Science, queries and calculations by Fraunhofer ISI

6.4 Scientific Profiles

In a final step, we will take a closer look at the scientific profiles, i.e. the shares of publications across scientific disciplines, of the universities and PROs Figure 37-Figure 43. It becomes obvious that Fraunhofer has the largest shares in physics, materials research and electrical engineering. Interestingly, the shares in computers have declined over the years, while other fields like specific engineering, optics, medicine and basic chemistry have grown. As for the MPG, the largest shares can be found in physics, followed by basic chemistry and biotechnology. In addition, there seems to be a tendency to switch from materials research, where the shares have slightly declined over the years, to biology, where the shares have increased. For the HGF, also physics is the largest field in terms of publications, followed by medicine and materials research. Also the fields ecology, climate, biotechnology, basic chemistry and biology reach shares above 5%. Although it has been a decline over the years, also the WGL still has the largest publication shares in physics, followed by biology which has increased rather massively in the last years. For the WGL, also medicine, materials research, ecology, climate biotechnology and basic chemistry are important fields.

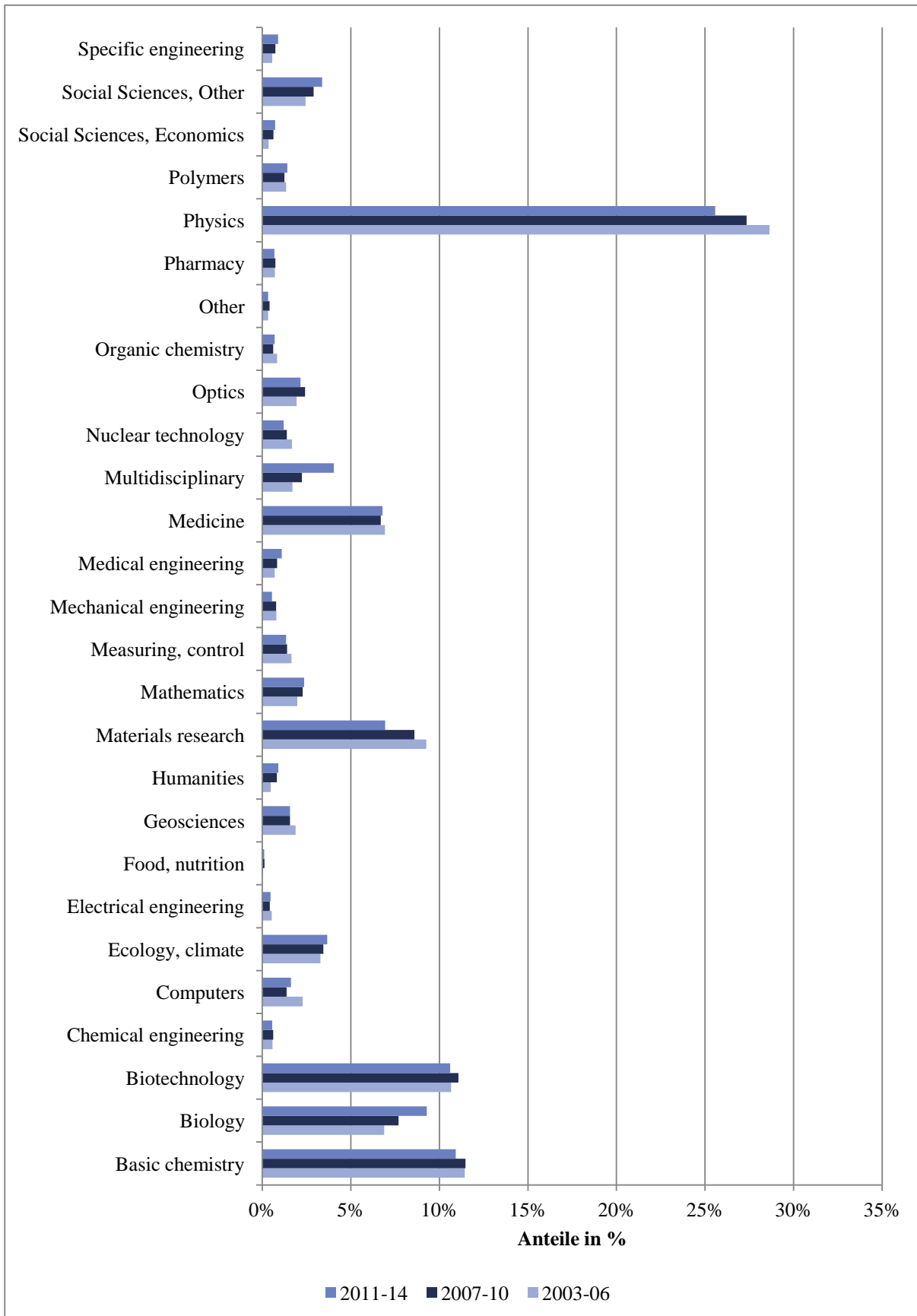
When looking at the universities, it becomes obvious that also physics still is an important field, it has a lower weight than in the case of the PROs. Here, medicine has much larger share. However, also the importance of biotechnology, biology and basic chemistry becomes obvious. For the "Fachhochschulen" a similar focus as for the universities becomes visible, although the profile is somewhat broader. For the nine large technical universities in Germany, the TU9, once again a larger focus on physics can be observed.

Figure 37: Scientific profile for FhG for the periods 2003 to 2006, 2007 to 2010, 2011 to 2014



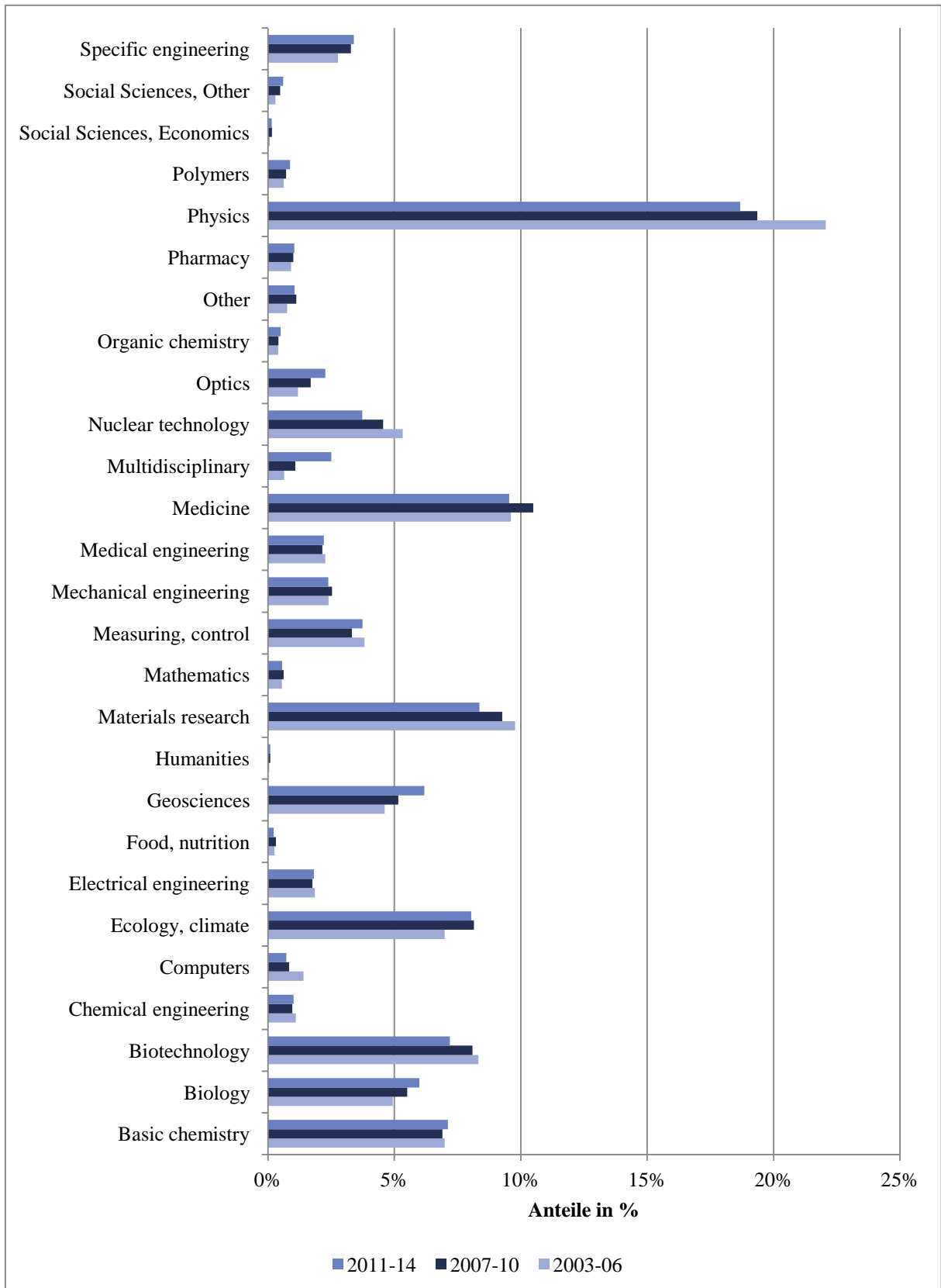
Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 38: Scientific profile for MPG for the periods 2003 to 2006, 2007 to 2010, 2011 to 2014



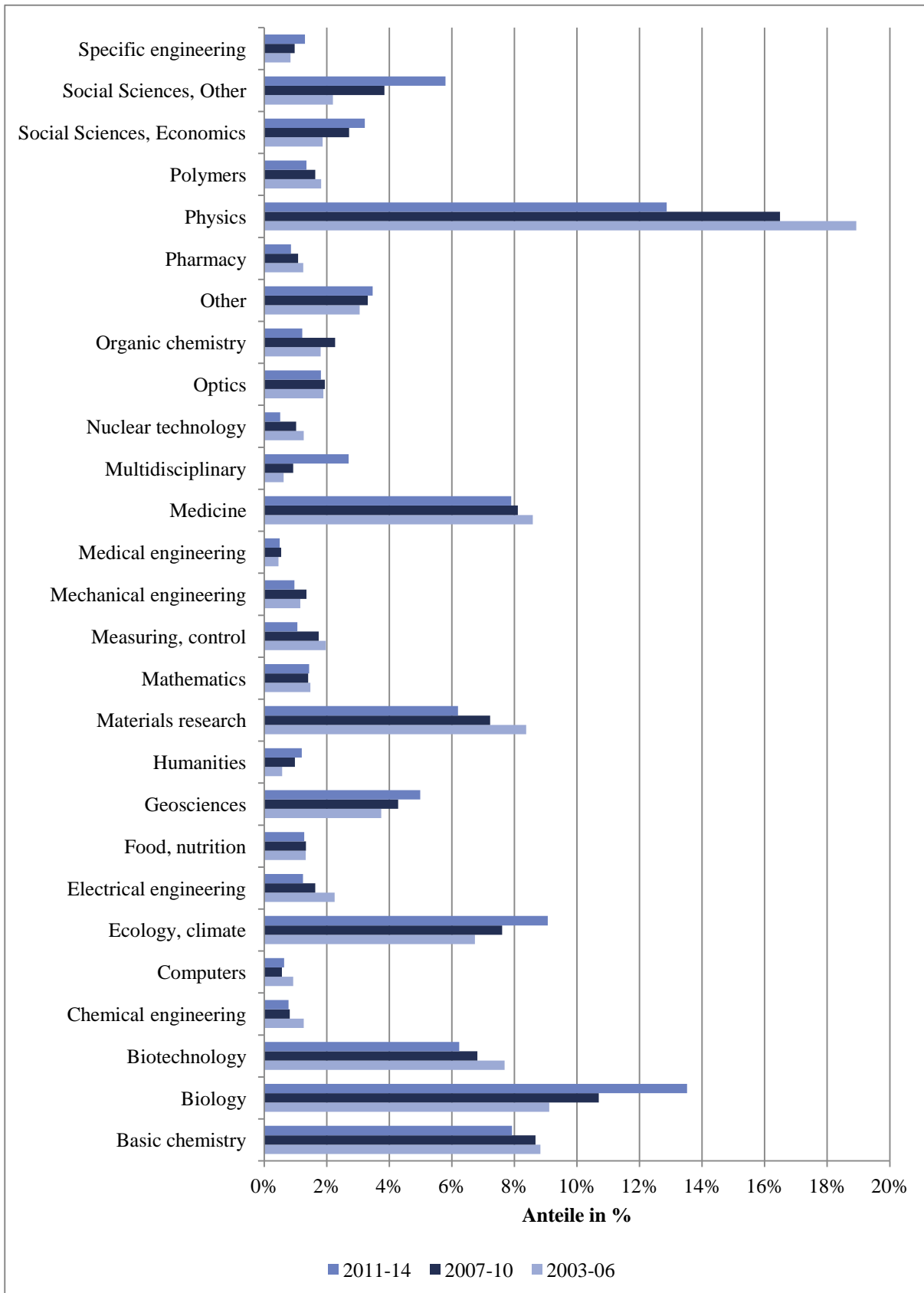
Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 39: Scientific profile for HGF for the periods 2003 to 2006, 2007 to 2010, 2011 to 2014



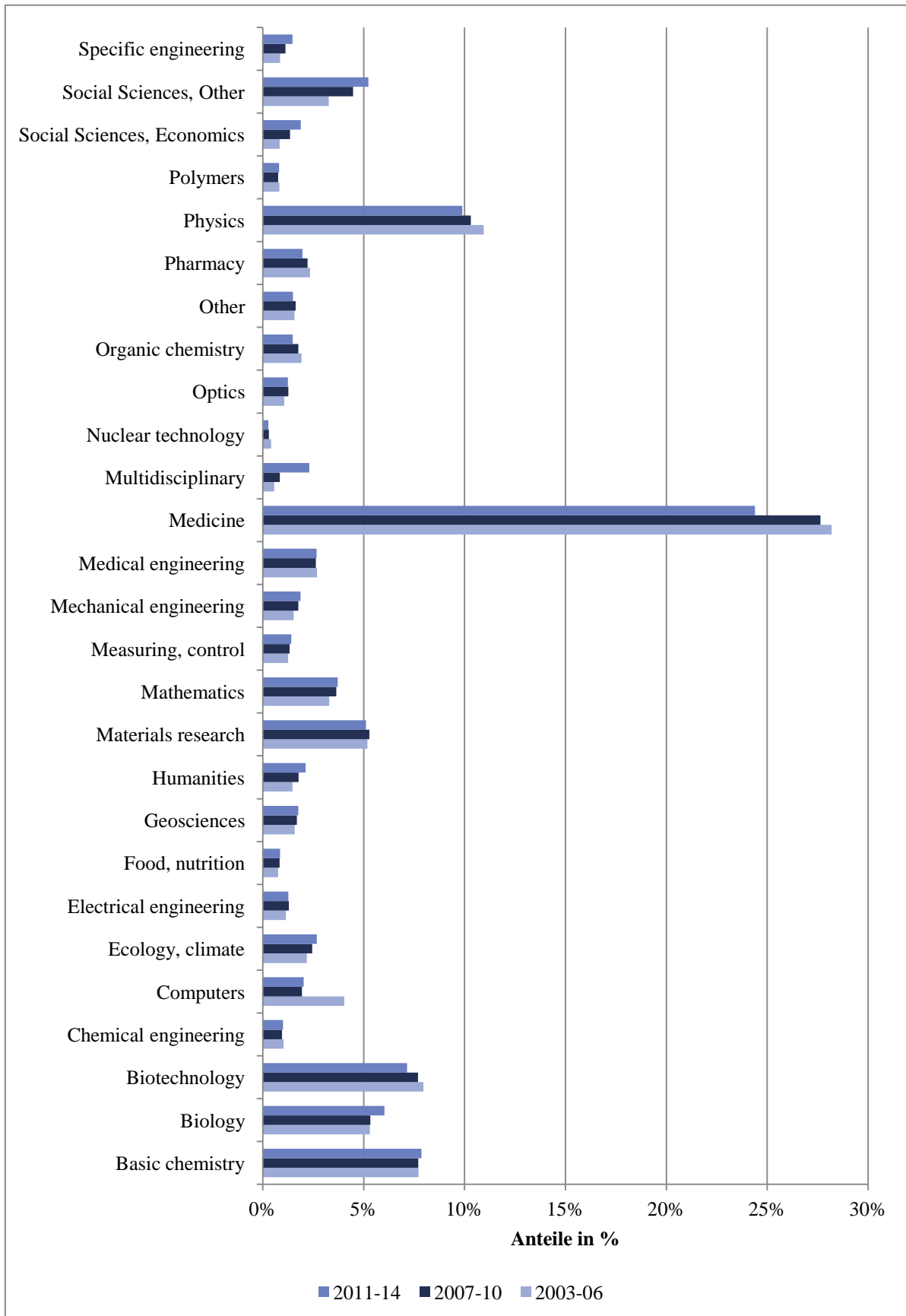
Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 40: Scientific profile for WGL for the periods 2003 to 2006, 2007 to 2010, 2011 to 2014



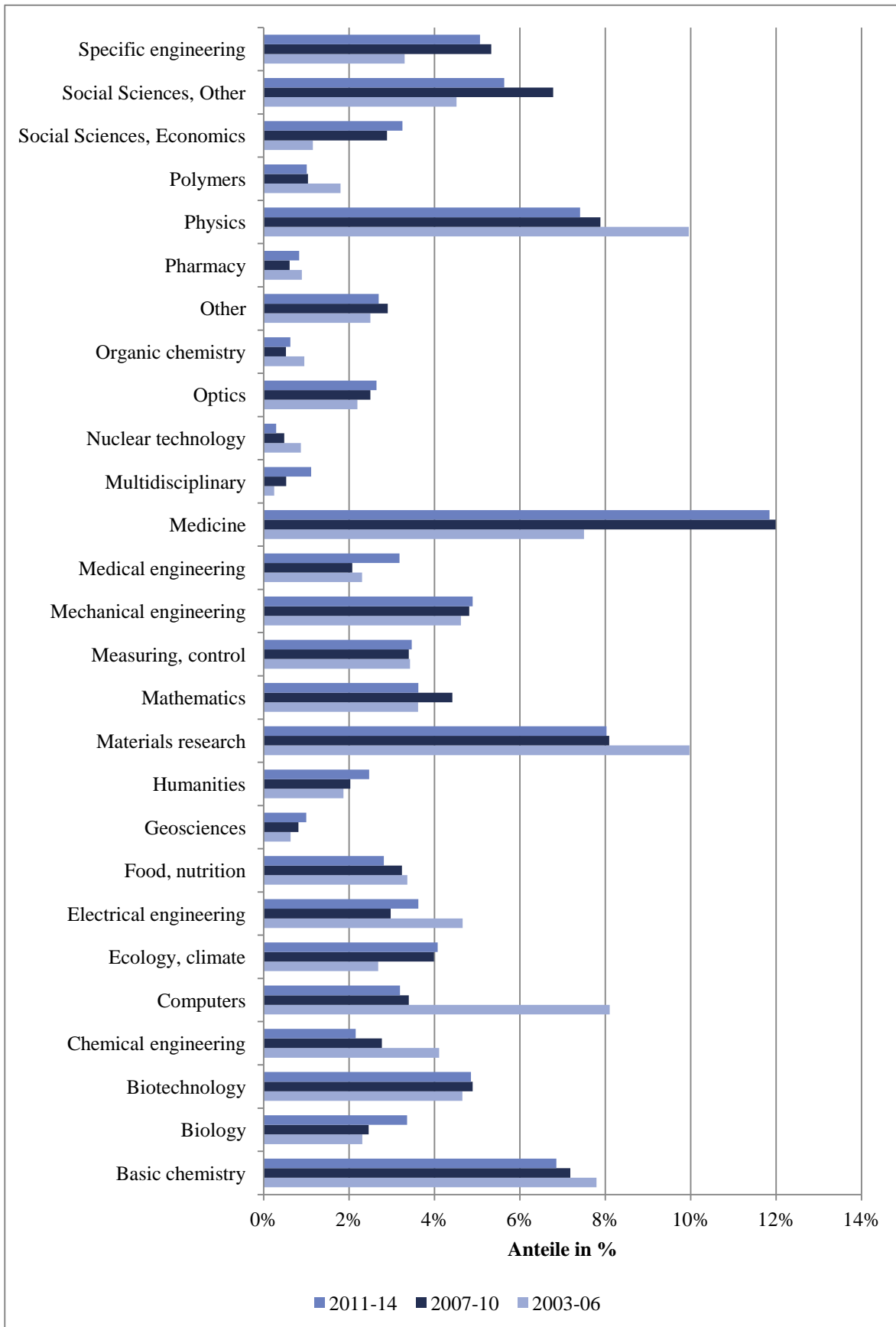
Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 41: Scientific profile for Universities for the periods 2003 to 2006, 2007 to 2010, 2011 to 2014



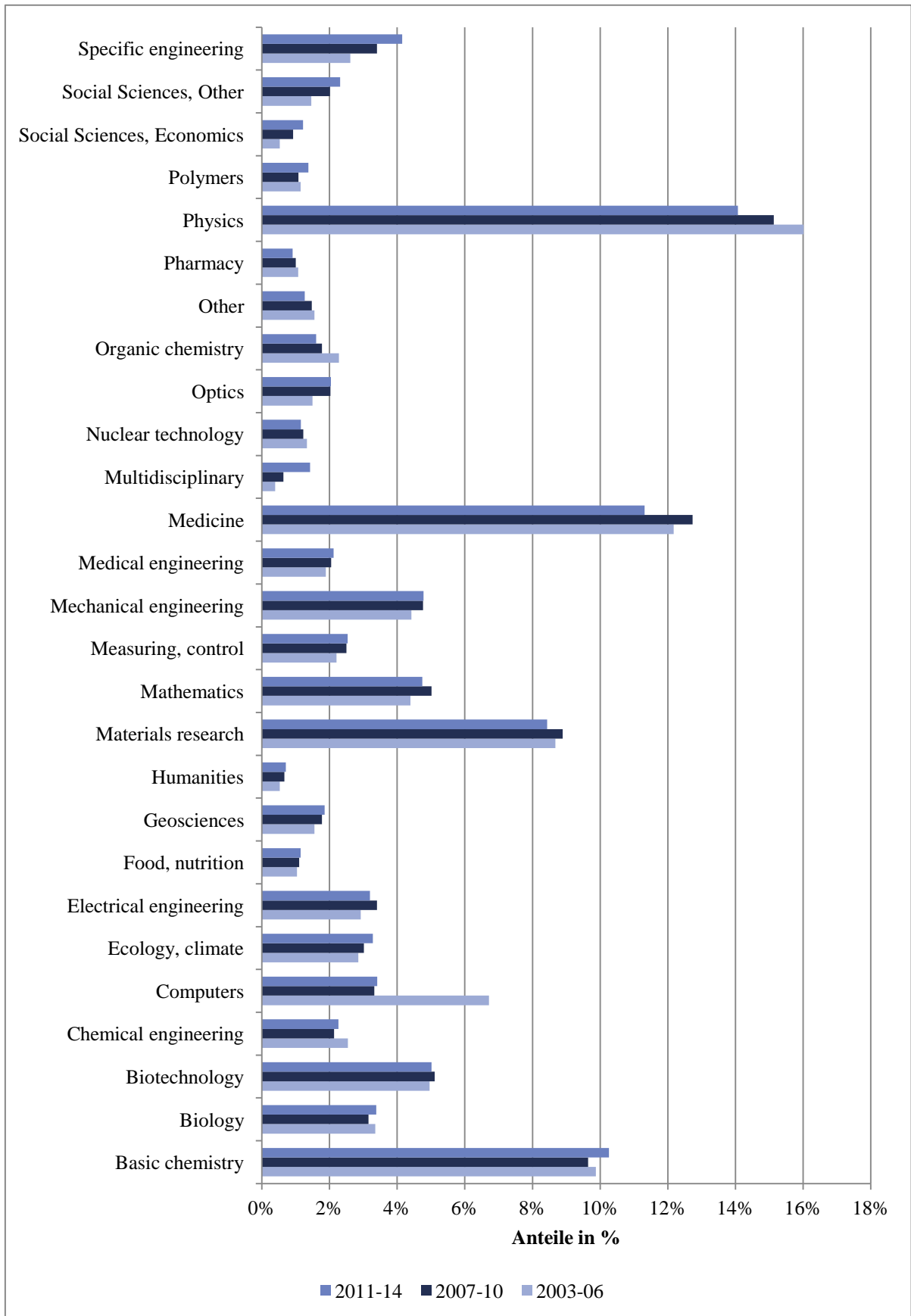
Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 42: Scientific profile for Universities of Applied Sciences (FH) for the periods 2003 to 2006, 2007 to 2010, 2011 to 2014



Source: Web of Science, queries and calculations by Fraunhofer ISI

Figure 43: Scientific profile for TU9 for the periods 2003 to 2006, 2007 to 2010, 2011 to 2014



Source: Web of Science, queries and calculations by Fraunhofer ISI

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Appendix: Country Code list

Country	Country code
Austria	AT
Belgium	BE
Brazil	BR
Canada	CA
China	CN
Corea	KR
Denmark	DK
Finland	FI
France	FR
Germany	DE
India	IN
Israel	IL
Italy	IT
Japan	JP
Netherlands	NL
Poland	PL
Russia	RU
South Africa	ZA
Spain	ES
Sweden	SE
Switzerland	CH
United Kingdom	GB
USA	US
European Union until April 2004	EU15
Newer member states of the European Union	EU13
European Union	EU28