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Performance and Structures of the German Science System in an International Comparison 2009 with a Special Focus on East Germany

Analyses carried out for the annual report of the Expert Commission on Research and Innovation

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Abstract

The report analyses the performance and structures of the German science system in an international comparison based on publications recorded in the database Science Citation Index. As major observation, the share of Germany and other advanced countries in international reputed journals decreases due to a steadily growing activity of catching-up countries, in particular China. At the same time, the scientific regard of Chinese publications is improving, but the majority of publications still appears in journals with limited international visibility.

As to a more detailed structural analysis, the performance of Germany is particularly high in the fields optics, measurement/ control, medical technology, polymers and physics, where both bibliometric performance indicators, Scientific Regard and International Alignement, are positive distinctly above average.

A shift share analysis examines the growth of the scientific fields more in-depth. According to this, the general decrease of the German share is even much stronger in organic chemistry, polymers, chemical engineering, and materials research; an increase can be observed only for ecology/ climate and geosciences.

The publication analysis for the former East Germany reveals that it has almost achieved the performance level of West Germany. Specific strengths of East Germany can be found in physics, ecology/climate and geo sciences. Specific areas of specialization in Berlin are optics, medical technology and medicine.

Since a few years, the database SCOPUS is available as alternative to the Web of Science (WoS). The comparison of both files shows that the number of publications in SCOPUS is substantially higher than that of WoS, in particular in the engineering and social sciences as well as in the humanities. However, many documents in SCOPUS do not provide a country code, so that the database has to be completed for meaningful country analyses.

1. Introduction to this Issue

The scientific capability of a country is an essential basis for its technological performance, which is why this topic has been regularly analyzed for many years in the context of studies on the German innovation system. The crucial contribution of science to technology development consists in educating highly skilled personnel whose quality depends to a considerable extent on the research capability. It goes without saying that the results of scientific research are also an essential foundation for technical development, whereby the connections between science and industry are frequently of an indirect nature and less obvious, particularly because in many cases a distinct time lag can be observed between activities in science and their impact on technology.

Scientific performance is difficult to measure, especially as the structures of the individual disciplines frequently vary distinctly. Statistical analysis of publications by experts has proved to be meaningful, inasmuch as they are conducted with a meticulous regard for methodology. The analyses presented here refer not only to science areas with a close link to technology, but to the natural, life and engineering sciences as a whole. In this context, the number of publications and citations is analyzed as a performance indicator in an international comparison. Furthermore, the international changes in this structure of sciences are examined by a shift-share analysis. A special feature refers to the situation of scientific activities in former East Germany twenty years after German unification. A special chapter is devoted to a comparison of the bibliometric databases Science Citation Index (SCI) and SCOPUS for investigating new potentials of bibliometric analysis.

The data for the analysis of Germany's scientific performance in an international comparison were provided in September 2009, the comparison of the SCI and SCOPUS was performed in October 2009.

2. Scientific Performance Reflected by Bibliometric Indicators

2.1 Methodological Basis

The bibliometric analyses were carried out utilizing the Science Citation Index (SCI), a multidisciplinary database covering a broad spectrum of disciplines. The searches cover the natural and engineering sciences as well as medicine and life sciences. The database deals above all with English language journals, which is unproblematic for most fields. German engineering sciences which mainly publish in the German language, however, are inadequately recorded. Generally, journals are reviewed in the SCI which are frequently cited, i.e. with high visibility, so that primarily higher quality publications are taken into consideration. Thus the mere fact that a paper is recorded in the SCI, respectively that it appears in journals covered by the SCI, can be considered a first indicator of quality.

Besides the absolute number of publications which are available up to the year 2008, citations in particular will be utilized as performance indicators. To estimate the citation rates, citations from the actual year of publication and the two following years are considered, so that a standard time window of three years forms the basis for all years considered. For this reason, citation rates can only be calculated up to the year of publication 2006. As this type of analysis is quite complex, a special preparation of the SCI is necessary; the data for this report were provided by the Centre of Science and Technology Studies (CWTS) at the University of Leiden, the Netherlands.

For a more exact analysis of the citation quotas, the calculation of two additional indicators is meaningful, the "journal-specific Scientific Regard" (SR Index, in German: z*eitschriftenspezifische Beachtung*) and the "International Alignment" (IA Index, in German: *internationale Ausrichtung*). The indicator "Scientific Regard" states whether the articles of a country / a region are cited on average more frequently or more seldom than the articles in the journals in which they appeared. Positive indexes point to an above-average citation rate; values of zero correspond to the world average. Through reference to the journal in question the disadvantages of countries which have less than optimum access to big English language journals are compensated for. Furthermore, the different citation behaviour between disciplines is compensated. The indicator is calculated as follows:

$$SR_k = 100 \tanh \ln (OBS_k/EXP_k)$$

In this equation, OBS_k means the actually observed citation frequency of publications from country k. EXP_k is the expected citation rate which results from the average citation frequency of the journals in which the authors of this country have published their articles.

In addition to this, the indicator "International Alignment" shows whether the authors of a country publish in internationally visible or in less visible journals, judged against the world average. Through a high quota of publications in internationally visible journals an intensive participation in the international scientific discussion is documented. Similar to the SR Index, positive values in the IA Index signify an above-average international orientation. The IA Index is calculated as follows:

$$IA_k = 100 \tanh \ln (EXP_k/OBS_w)$$

The same conventions apply as for the SR index. The index w stands for the world as a whole.

In order to compensate for possible distortions through database coverage in the analysis of absolute publication numbers, the specialization index RLA (Relative Literature Advantage) is calculated. The corresponding equation is:

$$RLA_{ij} = 100 \tanh \ln [(Publ_{ij} / \sum_i Publ_{ij}) / (\sum_j Publ_{ij} / \sum_{ij} Publ_{ij})]$$

Here i stands for the country and j for the field. The RLA Index is so constructed that its scale of values encompasses ± 100 with the neutral value 0. Positive values indicate an above-average specialization, and negative values a below-average one, whereby the world average serves as a reference.

2.2 Scientific Publications from Germany in an International Comparison

The journals covered by the SCI change steadily, in particular, the number of journals is slowly increasing. Therefore it is not meaningful to consider absolute numbers of publications, but rather the shares of the selected countries in all SCI publications (Table 1). In former years a gradually decreasing share of Germany since the year 2001 has already been observed, which however also applied to other large industrialized countries such as the USA, Japan, Great Britain or France. This phenomenon can be explained by the increase of publications from catching-up countries like China, India, South Korea or Brazil. As the number of journals in the SCI is limited and thus also the number of publications it contains, the growing strength of the catching-up countries leads to a visible displacement effect, at the expense of established actors. In 2008 this general trend became even more accentuated. In particular the shares of Japan, Great Britain and Sweden sharply decreased, while the German reduction remained moderate. If the publication share of the year 2000 is indexed to the level 100, then the index for Germany in the year 2008 lies at 85.5% (Table 2). Among the industrialized countries only Canada and Italy still had an index above 100 in 2008. In contrast to the industrialized countries, South Korea achieved an index of 173 and China even of 191. Relatively new is the separate presentation of the new EU Member States for which an increase in the share of the worldwide publications can be observed as well, however, at a much more modest scale than in South Korea or China.

Table 1: Shares of Selected Countries and Regions in all Publications in the SCI

Country/ region	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
USA	35.1	34.3	33.7	32.9	32.3	31.9	32.1	31.9	31.7	31.4	30.8	30.5	29.9	28.3
JPN	9.1	9.5	9.5	10.0	10.2	10.2	10.2	10.1	10.0	9.4	9.0	8.5	8.2	7.5
GER	7.9	8.2	8.6	9.0	9.0	9.0	9.0	8.8	8.7	8.4	8.4	8.2	8.0	7.7
GBR	9.5	9.6	9.3	9.4	9.3	9.4	9.1	8.8	8.6	8.4	8.2	8.1	8.1	7.5
FRA	6.3	6.4	6.6	6.7	6.7	6.6	6.6	6.4	6.4	6.1	6.0	5.9	5.8	5.8
SUI	1.8	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0	1.9
CAN	4.7	4.7	4.4	4.3	4.3	4.3	4.1	4.2	4.3	4.3	4.4	4.5	4.6	4.4
SWE	2.0	2.1	2.1	2.1	2.1	2.0	2.1	2.1	2.0	1.9	1.9	1.8	1.8	1.7
ITA	3.9	4.2	4.2	4.3	4.4	4.4	4.6	4.7	4.8	4.8	4.7	4.7	4.9	4.8
NED	2.6	2.6	2.7	2.6	2.5	2.5	2.5	2.5	2.5	2.6	2.6	2.6	2.5	2.5
FIN	-	-	-	-	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.8
KOR	-	-	-	-	1.7	1.9	2.1	2.3	2.6	2.8	3.0	3.1	2.9	3.3
CHN	-	-	-	-	-	-	-	5.2	5.8	6.5	7.6	8.6	9.3	9.9
EU 15	-	-	-	-	40.9	40.7	40.6	39.9	39.4	39.4	38.8	38.4	38.0	36.8
EU 12*	-	-	-	-	-	-	-	3.4	3.4	3.5	3.5	3.5	3.5	4.1
EU 27**	-	-	-	-	-	-	-	42.4	41.9	42.0	41.3	40.9	40.4	40.1
World	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*Data till 2005 refer to the EU-10, from 2006 to EU-12; **Data till 2005 refer to EU-25, from 2006 to EU-27.

Sources: SCI, searches by University of Leiden (CWTS), calculations by Fraunhofer ISI.

When the citation rates are scrutinized, the particularly good positions of Switzerland, the United States and the Netherlands emerge (Table 3). All three countries were able to strengthen their already good position further, whereby Switzerland succeeded in extending its leading position since 2004. Germany was also able to continue the positive trend of the past years, which however had no impact on its relative positioning compared with other actors, as in recent years the citation quotas improved in almost all countries investigated. Also, the worldwide average citation numbers rose slightly. This observation can point to a general structural change in the database, for instance, an increase in the number of journals covered, which leads to an increase in the number of potentially citing publications.

Table 2: Shares of Selected Countries and Regions in all Publications in the SCI in the Period 2000 to 2006 indicated to the Year 2000 (Index = 100)

Country/ region	2000	2001	2002	2003	2004	2005	2006	2007	2008
USA	100	100.7	100.2	99.5	98.5	96.7	95.7	94.0	88.9
JPN	100	100.6	99.1	98.7	92.4	88.2	83.5	80.8	74.3
GER	100	99.6	97.6	95.7	93.3	92.9	90.4	88.5	85.5
GBR	100	96.4	93.3	91.0	89.5	87.0	86.0	86.2	80.1
FRA	100	99.8	97.2	96.8	92.2	91.9	89.6	87.5	88.5
SUI	100	96.7	95.8	99.0	99.3	98.3	99.2	100.8	97.8
CAN	100	96.4	98.2	99.7	100.7	104.2	106.0	106.8	103.2
SWE	100	103.7	101.4	97.6	94.4	93.5	90.1	90.8	83.0
ITA	100	104.0	105.7	108.2	109.5	107.6	107.5	111.2	108.4
NED	100	99.7	100.8	101.0	101.3	102.8	102.2	101.0	97.4
FIN	100	100.0	96.7	96.8	94.5	90.4	91.4	89.7	84.4
KOR	100	113.6	123.2	137.6	150.0	159.9	162.5	157.0	173.4
CHN			100	111.4	125.8	146.8	166.0	179.7	191.1
World	100	100	100	100	100	100	100	100	100

Sources: SCI, searches by University of Leiden (CWTS), calculations by Fraunhofer ISI.

While China demonstrates the greatest development dynamic with regard to the number of annual publications, its citation quota is still relatively low, despite continual increases. However, the score is in the meantime slightly above the value which was calculated for the new EU Member States and it nearly reaches that of South Korea.

Table 3: Citation Rates (3 year window) of Selected Countries and Regions in Publications in the Science Citation Index (without self-citations)

Country/ region	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
USA	4.8	4.8	5.0	4.7	5.1	4.9	4.9	5.1	5.2	5.4	5.3	5.4
JPN	2.5	2.4	2.6	2.5	2.6	2.4	2.6	2.8	2.8	3.1	3.0	3.2
GER	3.4	3.5	3.6	3.3	3.6	3.6	3.6	3.9	4.0	4.3	4.4	4.5
GBR	3.6	3.5	3.9	3.6	3.7	3.6	3.8	4.4	4.5	4.8	4.8	5.0
FRA	3.2	3.2	3.3	3.1	3.2	3.2	3.4	3.5	3.6	3.8	3.9	4.1
SUI	5.0	5.1	5.4	4.7	5.1	5.0	5.0	5.2	5.2	5.6	5.7	5.8
CAN	3.4	3.6	3.8	3.6	3.8	3.4	3.8	4.0	4.2	4.3	4.3	4.6
SWE	3.6	3.5	3.7	3.4	3.7	3.8	3.9	4.0	4.5	4.5	4.6	4.9
ITA	2.9	2.9	3.1	2.9	3.2	2.7	3.0	3.3	3.4	3.6	3.8	3.9
NED	4.0	3.8	4.2	3.9	4.4	4.1	4.3	4.4	5.0	5.2	5.2	5.4
FIN	-	-	-	-	3.2	3.7	3.6	3.9	3.8	4.3	4.1	4.3
KOR	-	-	-	-	1.7	1.9	1.9	2.1	2.3	4.3	2.5	2.7
CHN	-	-	-	-	-	-	-	1.6	2.0	2.2	2.3	2.6
EU 15	-	-	-	-	3.3	3.3	3.3	3.5	3.7	4.3	3.9	4.1
EU 12	-	-	-	-	-	-	-	1.9	2.1	2.1	2.2	2.4
EU 27	-	-	-	-	-	-	-	3.4	3.5	3.7	3.8	3.9
World	3.0	3.0	3.2	2.9	3.1	3.0	3.2	3.3	3.4	3.6	3.6	3.7

Sources: SCI, searches and calculations by University of Leiden (CWTS), calculations by Fraunhofer ISI.

Table 4 reports the result for the indicator journal-specific scientific regard (SR index). For Germany, this index has been slightly declining since the mid 1990s and at present shows up a further decrease. On the whole, the German value is comparable with that of other leading industrialized countries like the USA, Great Britain or Canada. Switzerland holds by far the leading position with regard to the SR index. For China a steady improvement can be observed.

In the German perspective, the development of the International Alignment (IA index) has been positive for many years (Table 5). Here a positive trend observed since the beginning of the 1990s continues, i.e. the efforts to be broadly integrated in the international scientific discussion are being successfully continued. On the whole, German authors are increasingly successful in placing their articles in reputed international journals. The slightly decreasing Scientific Regard Index for Germany may be linked to this increasing international presence, as the Scientific Regard is calculated with reference to the journals where the articles are published.

The leading countries as to the International Alignment Index are the United States, Switzerland and the Netherlands. Similar to the Scientific Regard Index, most country values for the International Alignment improved in the past years, in particular, the indexes of Great Britain, Japan, France, and Italy. The values for Korea, China and the new EU Member States are distinctly negative, but improving as well.

Table 4: Scientific Regard (SR Index) of Selected Countries and Regions in Publication in the Science Citation Index (without self-citations)

Country/ region	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
USA	10	11	11	11	9	9	9	10	9	9	8	7
JPN	-7	-8	-7	-4	-7	-6	-7	-7	-10	-9	-10	-8
GER	9	9	7	8	7	7	8	8	7	7	7	6
GBR	9	5	4	3	8	9	9	10	7	8	8	8
FRA	4	4	3	2	1	3	2	1	2	2	1	3
SUI	20	23	22	17	15	17	17	16	17	15	15	16
CAN	5	6	5	9	5	9	3	4	6	5	4	6
SWE	12	13	14	12	15	9	8	9	11	9	8	11
ITA	-4	-5	-5	-4	-3	-2	-4	0	-5	-2	-1	0
NED	13	10	15	14	10	7	11	8	13	11	9	9
FIN	-	-	-	-	2	7	8	8	3	2	4	9
KOR	-	-	-	-	-16	-11	-11	-9	-5	-2	4	-3
CHN	-	-	-	-	-	-	-	-11	-1	1	3	4
EU 15	-	-	-	-	2	2	2	2	2	2	2	2
EU 12	-	-	-	-	-	-	-	-15	-13	-11	-12	-8
EU 27	-	-	-	-	-	-	-	1	1	1	1	1
Welt	0	0	0	0	0	0	0	0	0	0	0	0

Sources: SCI, searches and calculations by Leiden University (CWTS), calculations by Fraunhofer ISI.

Table 5: International Orientation (IA Index) of Selected Countries and Regions in Publications in the Science Citation Index (without self-citations)[1]

Country/ region	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
USA	35	35	34	36	36	34	33	33	32	32	31	30
JPN	-15	-17	-14	-14	-14	-18	-11	-11	-10	-6	-7	-6
GER	3	4	3	3	5	7	6	8	9	11	13	16
GBR	7	6	11	10	12	15	15	19	19	20	21	21
FRA	-1	0	2	2	0	3	4	5	3	5	7	7
SUI	29	29	30	29	30	29	28	28	27	30	31	29
CAN	7	10	11	11	13	11	16	14	15	15	14	16
SWE	8	7	6	8	8	11	12	11	15	15	16	18
ITA	0	0	2	1	2	1	-1	-1	3	3	7	7
NED	14	13	13	14	21	20	19	21	24	26	27	28
FIN	-	-	-	-	8	10	6	8	9	8	9	8
KOR	-	-	-	-	-45	-38	-38	-37	-34	-32	-30	-29
CHN	-	-	-	-	-	-	-	-56	-47	-45	-42	-37
EU 15	-	-	-	-	1	3	2	4	5	6	8	8
EU 12	-	-	-	-	-	-	-	-38	-36	-38	-36	-32
EU 27	-	-	-	-	-	-	-	1	2	3	4	5
World	0	0	0	0	0	0	0	0	0	0	0	0

Sources: SCI, searches and calculations by Leiden University (CWTS), calculations by Fraunhofer ISI.

2.3 Germany's Citation Profile

In order to arrive at a more disaggregated consideration of Germany, the citation indexes were differentiated according to 26 sub-fields. 18 of these sub-fields demonstrate clear relations to technology, while the remaining 8 have a rather general character. This division was made in order to more clearly emphasize the relationship between science and technology in the context of the studies on the German innovation system (Schmoch 2000). Based on the indexes of Scientific Regard and International Alignment for the individual fields, country-specific profiles of strengths and weaknesses in

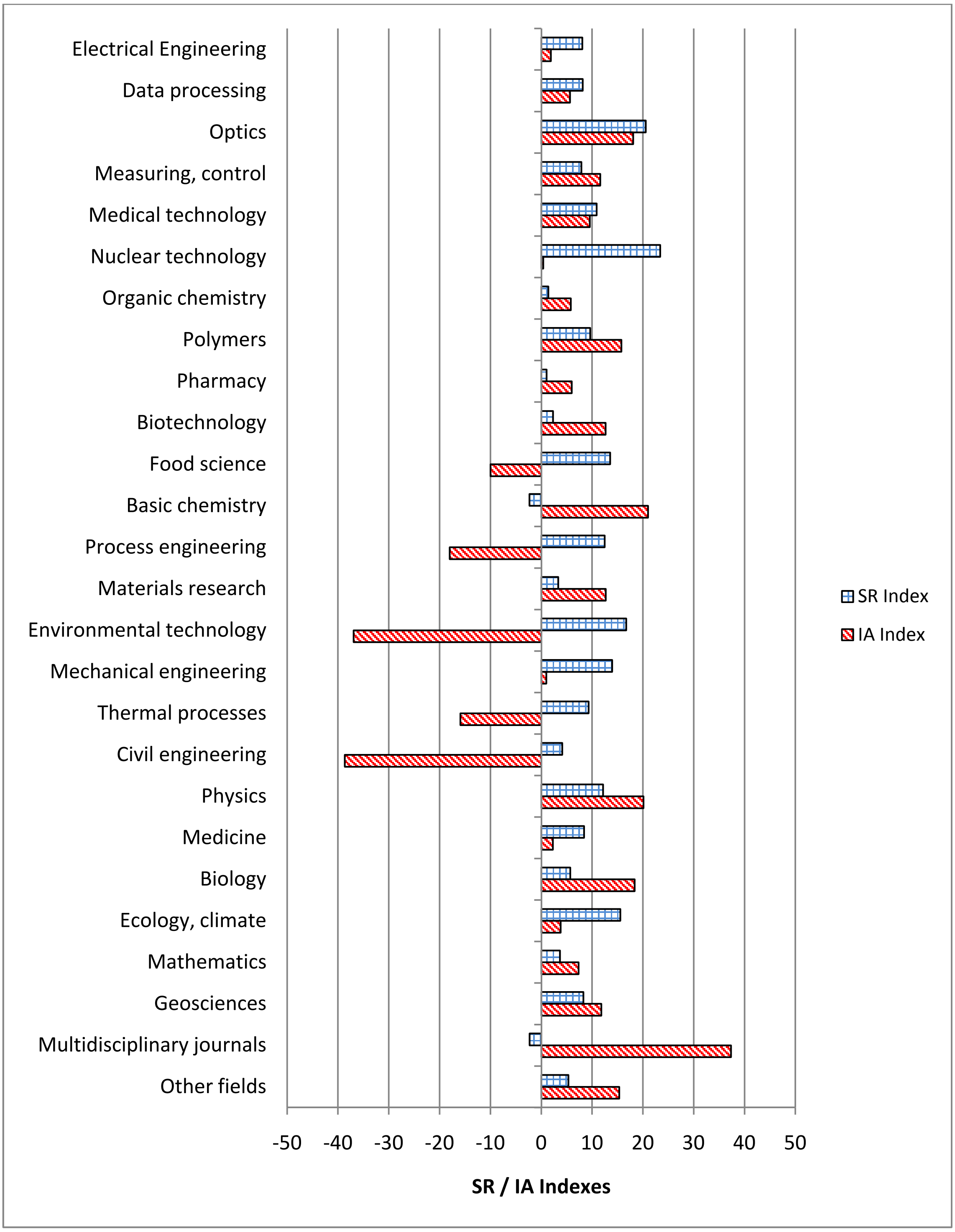
1 For Finland, Korea, the EU-15 and the new candidate countries, no data are available for 1993 and 1997.

the scientific performance can be drawn up. In Figure 1 the SR and IA indexes for Germany are presented conjointly. At first observation, the values of the SR and IA indexes vary considerably; some fields show average values, other fields quite high ones. In earlier reports, for instance, Schmoch and Qu (2009), it was demonstrated that the very high average values of Switzerland for both indexes are based on a uniform high level in all fields.

As to the comparison of the SR and IA indexes for Germany, the values are quite different in many fields. For example, in electrical engineering, nuclear technology or ecology, the SR index is high and the IA index average. Thus high SR indexes are achieved in less internationally visible journals. In other cases such as biotechnology, basic chemistry or materials, the IA index is high, but compared to the level in these journals, the SR indexes are moderate. Only in a few fields, in particular optics, measuring/ control, medical technology, polymers and physics, are above average values achieved for both indexes.

As already stated in earlier reports, some fields in engineering, in particular chemical engineering, environmental engineering, thermal processes and civil engineering, display extremely low IA indexes. This observation does not reflect a low international orientation of German authors, but rather a bad coverage of the engineering fields – apart from the US journals – in the Science Citation Index database. All in all, the findings of the German profile suggest that a better balance between Scientific Regard and International Alignment should be aimed for in various fields.

Figure 1: Scientific Regard (SR) and International Alignment (IA) of Germany in Publications in the Science Citation Index (without self-citations) Differentiated acc. to Science Fields, 2006



Sources: SCI, searches and calculations by Leiden University (CWTS), calculations by Fraunhofer ISI.

3. Structural Change in Science

This chapter deals with the breakdown of growth rates of scientific publications into different components in order to describe structural changes in sciences. At the same time, it is determined whether the countries considered engaged in sectors of dynamic growth or less growth-intensive ones in the last years. The dynamic publication analysis is based on a structural breakdown of the growth of the publication numbers. The method of structural decomposition – the so-called shift-share analysis – generally supports the analysis of trade structures. In that context it is called "constant market share analysis". In a modified and simplified form, the shift-share analysis is also used in regional research. Its application is relatively new in the field of publication statistics.

3.1 Methodology

The starting point of the structural analysis is the descriptive analysis of publication data observed in the former chapter, with the question whether a country has increased or decreased its publication share in the course of time. In particular, the growth rates of the publication shares in the period from 1998 to 2008 are considered. Then the aggregate growth rates for each field are subdivided, so that the structural components of change can be isolated. On this basis, conclusions can be drawn as to which effects induced the increase or decrease of a country's share within all scientific publications worldwide. In particular, the following effects are considered:

- Trend effect: it describes whether the growth or reduction of the country's share is due to the total change - increase or decrease – of all publications worldwide.
- Structure effect: this effect captures to what extent the growth or decrease of a country's publications is linked to a worldwide growth or decrease in the specific fields considered. So a publication profile with focus on fields with increasing relevance implies high structural effects.
- Intensification effect: it describes whether the growth of a country's publications refers to an active additional involvement in growing fields or a reduced engagement in generally decreasing field or vice versa.

The underlying formulas are documented in Frietsch and Breitschopf (2003) in detail, taking the example of patent analysis, and in (Frietsch et al. 2010).

As we consider, on analogy with the analysis in chapter 2.2 not the absolute publication numbers, but the shares of countries within all publications worldwide, we do not refer in the analysis to the worldwide totals of the publications shares – 100 percent at the beginning and the end of the observation period - but rather to the growth of the absolute worldwide publication numbers.

3.2 Findings

The results of the shift-share analysis for the countries considered are documented in Table 6. Therein, the change of shares between 1998 and 2008 is shown in absolute and relative terms. For instance, in the case of Germany, the share of publications within worldwide publications decreased from 8.36 to 7.23%, thus by 1.13% in absolute terms, equivalent to 13.5% in relative terms, with reference to the share of the starting year.

Table 6 reflects the findings of Table 2, that the established industrial countries displayed a decrease in the last ten years – with the exception of Switzerland, Canada, and Italy - whereas the threshold countries Korea and China show a very high growth. The quite extreme growth rate of Korea and China are primarily due to the very low absolute publication numbers in 1998, the starting year of the analysis.

A further interesting observation is that in almost all cases the trend effect and the adaptation effect have the same order of magnitude, but in most cases opposite algebraic signs. For instance, the trend effect of Germany is 3.6 and the adaptation effect -4.8, implying an absolute total growth 0f -1.1. This means that the share of Germany decreases in most fields more strongly than the general increase of the publications in the database. In the case of the three established countries with no decrease in absolute terms, the adaption effect is negative as well, but less pronounced than the positive trend effect.

Only in the cases of Korea and China is the adaptation effect positive, in particular for China, reflecting an enormous activity in all fields.

At first sight, it seems surprising that the structure effect is 0.0 for all countries. This is due to the fact that, for the total numbers, the general growth of publication activities is reflected by the trend effect and that the total numbers do not imply a structure. Therefore the mathematical formulation implies no value for the structural effect as to the total publication numbers of a country.

However, a structural effect appears with reference to specific fields as shown in Table 7 for the German case. But the size of the structural effect is generally lower than that of the trend and the adaptation effect. The differentiated analysis shows that some fields are more affected by the general decrease than others, in particular, the fields of electrical engineering, computers, basic chemistry, optics, organic chemistry, polymers, pharmacy, chemical engineering, nuclear technology, physics and materials research display a relative decrease of more than 20%. Some fields with this stronger decrease have good structural effects, for instance, optics, basic chemistry, materials research or physics, thus they had a good starting position in these fields and lost ground. A growth of the shares of publication can only be observed for civil engineering, ecology/climate, geosciences and multidisciplinary journals.

As for the United States, the highest decreases of more than 20% in relative terms are found for electrical engineering, environmental engineering, mechanical engineering, thermal processes, and mathematics. In Switzerland, the enormous relative growth rates above 40% in chemical engineering, mechanical engineering, civil engineering, ecology/climate, and geosciences are remarkable. Similar high growth rates can be established for Canada in electrical engineering, chemical engineering, and civil engineering.

In Korea, the high growth of more than the factor 2 is found for nuclear engineering, food/nutrition, civil engineering, medicine, and ecology/climate. In China fields with a relative growth above the factor 7 are food/nutrition, civil engineering, medical engineering, ecology/climate environmental engineering, and thermal processes. Thus in both countries research in ecology/climate is considerably strengthened.

To summarize, it is possible to detect relevant changes at the level of fields by means of the shift-share analysis, although the structures in science alter more slowly than in technology.

Table 6: Shift-share Analysis of SCI Publications for Selected Countries referring to the Period 1998 to 2008

Country	Trend effect	Structure effect	Adaptation effect	Abs. total growth	Rel. total growth
USA	13.7	0.0	-17.6	-3.9	-12.4
JPN	4.0	0.0	-6.2	-2.2	-23.9
GER	3.6	0.0	-4.8	-1.1	-13.5
GBR	3.9	0.0	-5.5	-1.6	-18.1
FR	2.7	0.0	-3.5	-0.8	-12.6
SUI	0.7	0.0	-0.7	0.1	3.2
CAN	1.8	0.0	-1.5	0.3	6.2
SWE	0.8	0.0	-1.1	-0.3	-16.1
ITA	1.7	0.0	-1.2	0.5	12.1
NED	1.0	0.0	-1.1	-0.1	-3.8
FIN	0.4	0.0	-0.4	0.0	-5.1
KOR	0.6	0.0	1.2	1.8	129.3
CHN	1.0	0.0	6.5	7.5	313.5

Sources: SCI. Searches by Leiden University (CWTS). Calculations by Fraunhofer ISI.

Table 7: Shift-share Analysis of German SCI Publications by Fields of Science referring to the Period 1998 to 2008

Field	Trend effect	Structure effect	Adaptation effect	Abs. total growth	Rel. total growth
Electrical engineering	2.0	-0.4	-2.1	-0.5	-26.4
Computers	3.3	-0.8	-4.5	-2.0	-26.4
Optics	4.0	1.6	-7.4	-1.8	-20.2
Measuring. control	3.7	-0.2	-4.9	-1.4	-16.0
Medical engineering	4.3	-0.5	-4.3	-0.5	-5.2
Pharmacy	3.3	0.1	-5.3	-1.9	-24.4
Nuclear technology	5.6	-4.2	-4.4	-2.9	-22.9
Basic chemistry	4.2	1.6	-8.4	-2.5	-25.9
Organic chemistry	4.5	-1.6	-5.9	-3.1	-30.1
Polymers	4.1	-1.0	-6.6	-3.5	-37.1
Biotechnology	3.8	-1.3	-3.5	-0.9	-10.6
Food. nutrition	2.8	1.3	-5.2	-1.0	-15.9
Chemical engineering	3.2	-2.2	-3.4	-2.3	-31.6
Materials research	4.6	2.7	-11.2	-3.9	-36.4
Environmental engineering	2.8	1.1	-5.0	-1.1	-17.8
Mechanical engineering	2.1	-0.3	-1.9	-0.1	-2.3
Thermal processes	2.1	0.4	-3.2	-0.7	-14.6
Civil engineering	1.5	1.0	-0.6	1.9	55.5
Physics	5.7	0.9	-9.3	-2.8	-21.4
Medicine	3.5	0.0	-3.9	-0.4	-5.2
Biology	3.6	-1.0	-3.3	-0.8	-9.4
Ecology. climate	2.8	2.0	-4.5	0.3	5.1
Mathematics	3.6	2.7	-8.3	-1.9	-22.4
Geosciences	3.2	0.7	-2.2	1.6	22.3
Other	2.3	0.4	-2.5	0.2	4.0
Multidisciplinary	1.9	-2.4	1.5	1.0	24.0
Total	**3.6**	**0.0**	**-4.8**	**-1.1**	**-13.5**

Sources: SCI. Searches by Leiden University (CWTS). Calculations by Fraunhofer ISI.

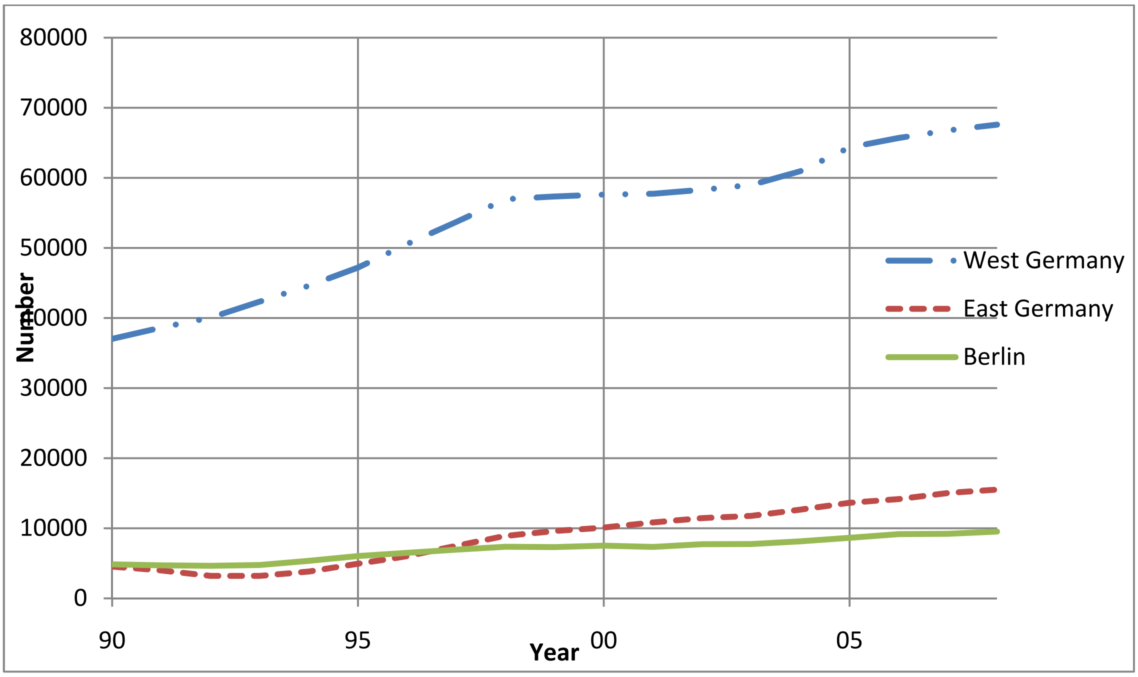
4. Scientific Activities in (Former) East Germany

Twenty years after German unification, it seems appropriate to analyze the structural changes in Germany during this time. In this chapter, the development of the number of publications in the last twenty years will be considered, with the publications originating in the former East German states being compared to those of the West German ones and of Berlin, with East and West Berlin taken together. Furthermore, a structural analysis of the scientific activities according to scientific fields is carried out. This analysis is based on publications recorded in the Science Citation Index (SCI) in its online version at the host STN.

Looking at the publications in that period, the number for East Germany was quite low compared to West Germany at the beginning of the 1990s. With reference to the population, about 350 publications per 1 million inhabitants were published in East Germany in 1995 compared to 740 in West Germany, thus the level of East Germany was less than 50% of West Germany. The number of publications per1 million inhabitants in Berlin reached 1,770, so it was higher than the West German level by the factor 2.4. This confirms the expectations that the publication level in a very large city will generally be higher than in a territorial state.

However, since that time the publication activities of East Germany increased considerably and as at a much higher speed than the publications in West Germany (Figure 2), and in 2008 the number of publications per 1 million inhabitants in East Germany was 1,190 compared to 1,030 in West Germany. Also in Berlin, the publication level increased to 2,810 per 1 million inhabitants; so also the publications in Berlin grew somewhat faster than in West Germany. As a first and immediate result, it can be stated, that in terms of absolute scientific activity, the growth process in East Germany in the last twenty years was successful.

Figure 2: Number of SCI Publications in East Germany, Berlin and West Germany



Sources: SCISEARCH (STN), searches and calculations by Fraunhofer ISI.

Looking at the impact of East German publications, the citations per publication in East Germany were at a level of 4.3 and are still somewhat lower than that of West Germany with 4.7 (Table 8). Looking at the citations in further detail, the main difference between East and West Germany is the higher international orientation of West German publications (IA index 16 compared to 10 for East Germany).

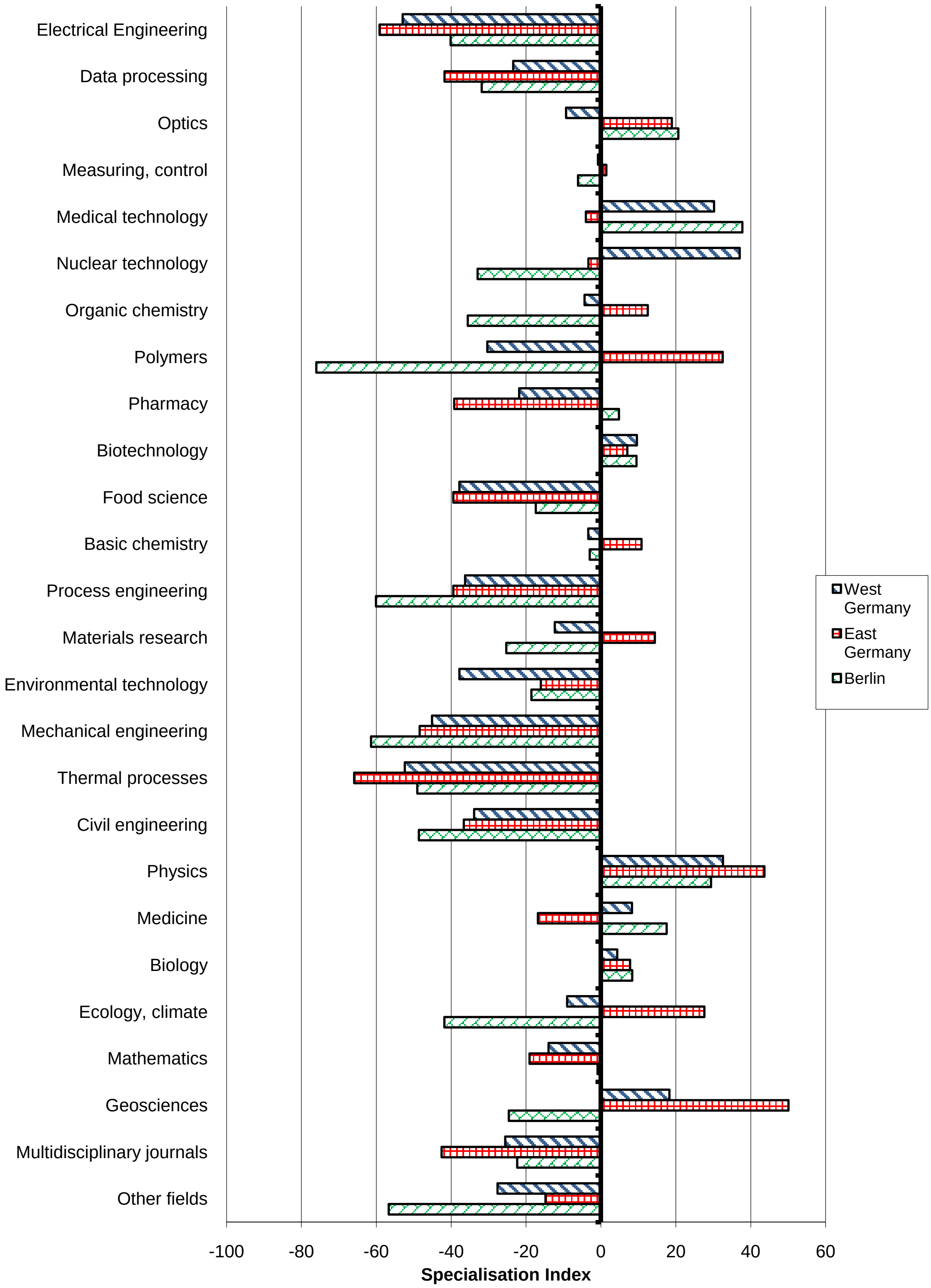
Table 8: Citation Scores of SCI Publications in 2006

Region	Citation rate	SR Index	IA Index
East Germany	4,3	7	10
Berlin	4,8	5	20
West Germany	4,7	8	16

Sources: SCI, searches and calculations by University of Leiden (CWTS), calculations by Fraunhofer ISI.

As to the publication profile of East Germany, a distinct focus on chemistry compared to West Germany becomes visible, reflected in positive specialization indexes in organic chemistry, polymers, basic chemistry and materials research (Figure 3). Furthermore, specific strengths of East Germany can be found in physics, ecology/climate and geo sciences. Specific areas of specialization in Berlin are optics, medical technology and medicine.

Figure 3: Specialization Profile of SCI Publications of East Germany, Berlin and West Germany



Sources: SCISEARCH (STN), searches and calculations by Fraunhofer ISI.

To illustrate the institutional structure in eastern Germany, the most relevant institutions in the fields organic chemistry, materials science, ecology/climate and geosciences are exemplarily documented in Tables 8 to 12. The publications of universities are only dominant in the field of organic chemistry. In the other three fields, non-university institutions, in particular Max Planck institutes, Helmholtz research centers and Leibniz institutes contribute in a relevant way. However, in such statistical lists the non-university institutions attend to appear at the top, as they are documented as institutes as a whole and not with their different departments, whereas at universities the individual institutes are generally indicated on scientific publications. A specific search for publications in 2008 shows that in 83% of the cases universities are involved, thus they are much stronger than they appear in the institutional lists.

Table 9: East German Institutions with Most Publications in Organic Chemistry in 2008

57	UNIV ROSTOCK, INST CHEM
55	UNIV ROSTOCK, LEIBNIZ INST KATALYSE EV
45	UNIV ROSTOCK, INST CHEM
20	UNIV ROSTOCK, LEIBNIZ INST KATALYSE EV
13	UNIV ROSTOCK EV, LEIBNIZ INST KATALYSE
9	UNIV LEIPZIG, INST ORGAN CHEM
8	TECH UNIV DRESDEN, DEPT CHEM
8	TECH UNIV DRESDEN, DEPT CHEM
7	ERNST MORITZ ARNDT UNIV GREIFSWALD, INST PHARM
7	UNIV LEIPZIG, INST ANORGAN CHEM
6	TECH UNIV BERGAKAD FREIBERG, INST ANORGAN CHEM
6	UNIV JENA, INST ANORGAN & ANALYT CHEM
6	UNIV JENA, INST ORGAN & MACROMOL CHEM
6	UNIV LEIPZIG, INST ORGAN CHEM

Sources: SCISEARCH (STN), searches and calculations by Fraunhofer ISI.

Table 10: East German Institutions with Most Publications in Materials Science in 2008

82	MAX PLANCK INST MICROSTRUCT PHYS
51	MAX PLANCK INST COLLOIDS & INTERFACES
38	MAX PLANCK INST CHEM PHYS FESTER STOFFE
32	IFW DRESDEN, INST MET MAT
26	GEOFORSCHUNGSZENTRUM POTSDAM
21	LEIBNIZ INST POLYMER RES DRESDEN
20	TECH UNIV DRESDEN, INST MAT SCI
14	FORSCHUNGSZENTRUM DRESDEN ROSSENDORF, INST ION BEAM PHYS & MAT RES
13	UNIV JENA, LAB ORGAN & MACROMOL CHEM
13	UNIV JENA, OTTO SCHOTT INST
11	UNIV JENA, INST MAT SCI & TECHNOL
9	TU CHEMNITZ, INST WERKSTOFFWISSENSCH & WERKSTOFFTECH
9	UNIV LEIPZIG, INST EXPT PHYS 2
9	UNIV POTSDAM, INST CHEM
8	IHP
8	TECH UNIV BERGAKAD FREIBERG, INST ORGAN CHEM
8	TECH UNIV DRESDEN, INST STRUKTURPHYS
8	UNIV HALLE WITTENBERG, INST CHEM

Sources: SCISEASRCH (STN), searches and calculations by Fraunhofer ISI.

Table 11: East German Institutions with Most Publications in Ecology/Climate in 2008

37	LEIBNIZ INST TROPOSPHER RES
69	MAX PLANCK INST BIOGEOCHEM, JENA
39	POTSDAM INST CLIMATE IMPACT RES
31	UFZ HELMHOLTZ CTR ENVIRONM RES, DEPT CONSERVAT BIOL
19	UNIV JENA, INST ECOL
18	TECH UNIV DRESDEN, IGW, INST GRUNDWASSERWIRTSCHAFT
12	UFZ HELMHOLTZ CTR ENVIRONM RES, DEPT COMPUTAT LANDSCAPE ECOL
9	GEOFORSCHUNGSZENTRUM POTSDAM
9	LEIBNIZ INST ATMOSPHER PHYS
9	VIRTUAL INST MACROECOL
8	MAX PLANCK INST EVOLUTIONARY ANTHROPOL
8	UFZ HELMHOLTZ CTR ENVIRONM RES, DEPT COMMUNITY ECOL
8	UNIV JENA, INST ECOL
8	UNIV POTSDAM, INST BIOCHEM & BIOL
7	GEOFORSCHUNGSZENTRUM POTSDAM
7	MAX PLANCK INST METEOROL
7	UFZ HELMHOLTZ CTR ENVIRONM RES, DEPT ANALYT CHEM
7	UNIV POTSDAM, INST GEOECOL
6	BALT SEA RES INST WARNEMUNDE
6	LEIBNIZ INST TROPOSPHER RES
6	UFZ HELMHOLTZ CTR ENVIRONM RES, DEPT ISOTOPE BIOGEOCHEM

Sources: SCISEARCH (STN), searches and calculations by Fraunhofer ISI.

Table 12: East German Institutions with Most Publications in Organic Chemistry in 2008

137	GEOFORSCHUNGSZENTRUM POTSDAM
34	MAX PLANCK INST BIOGEOCHEM
19	UNIV POTSDAM, INST GEOWISSENSCH
12	LEIBNIZ INST ATMOSPHER PHYS
12	UNIV JENA, INST GEOWISSENSCH
10	UNIV LEIPZIG, INST GEOL & GEOPHYS
6	UNIV LEIPZIG, INST GEOL & GEOPHYS
6	VIRTUAL INST MACROECOL
5	ERNST MORITZ ARNDT UNIV GREIFSWALD, INST BOT & LANDSCAPE ECOL
5	MAX PLANCK INST EVOLUTIONARY ANTHROPOL, DEPT HUMAN EVOLUT
5	TU BERGAKADEMIE FREIBERG, INTERDISCIPLINARY ENVIRONM RES CTR
5	UNIV LEIPZIG, INST METEOROL
4	ERNST MORITZ ARNDT UNIV GREIFSWALD, INST GEOG & GEOL
8	GEOFORSCHUNGSZENTRUM POTSDAM, DEPT GEODESY & REMOTE SENSING
4	LEIBNIZ INST BALT SEA RES
4	MAX PLANCK INST BIOGEOCHEM

Sources: SCISEARCH (STN), searches and calculations by Fraunhofer ISI.

All in all, relevant scientific institutional structures have been built up in eastern Germany in the last twenty years. The research activities of these institutions, primarily universities, are in many fields complementary to those of western Germany. In some specific areas non-university institutions were also established and play a relevant role.

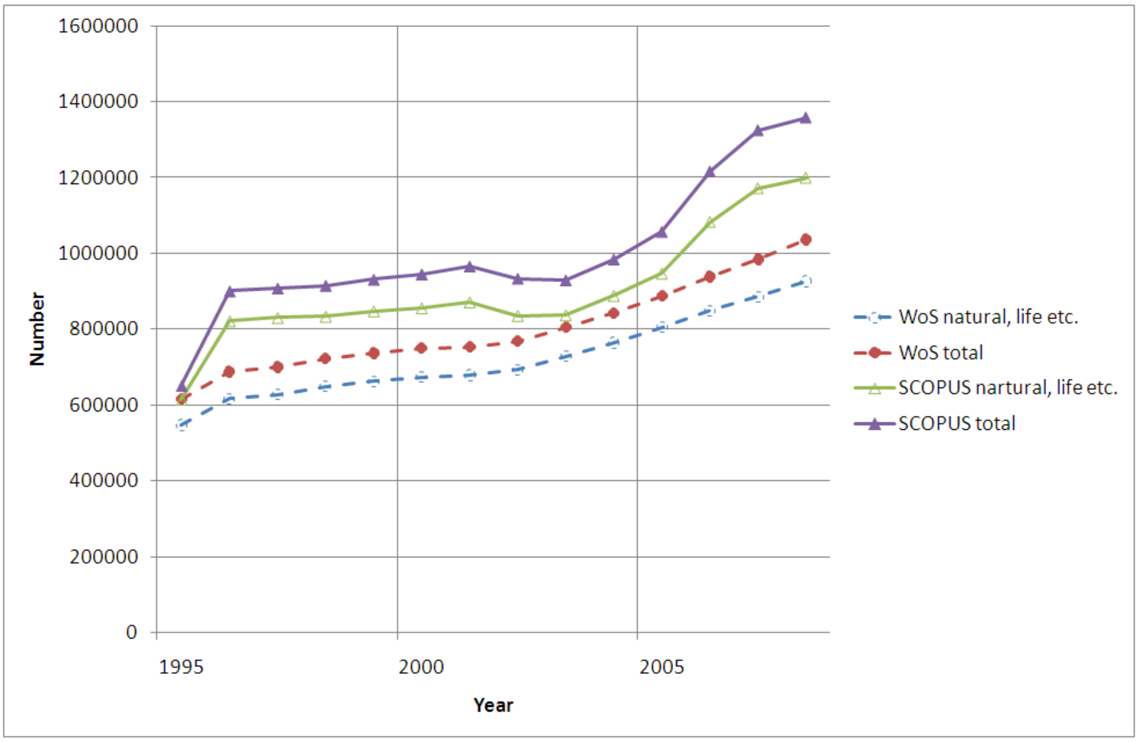
5. The Databases Web of Science and SCOPUS in Comparison

For many years, the database Web of Science (WoS) produced by Thomson Reuters with the partial databases Science Citation Index (SCI), Social Science Citation Index (SSCI) and Arts and Humanity Citation Index (A&HCI) was the only large multidisciplinary database with bibliometric features. The Web of Science was a monopoly and became the major reference for impact analyses of scientific publications. However, some years ago, the database SCOPUS produced by Elsevier appeared as a relevant alternative. In order to receive a first impression of the advantages and disadvantages of these databases, their coverage of fields and countries has been compared and is presented in this chapter.

In order to achieve an appropriate basis for the comparison, 21 larger fields of SCOPUS with an orientation to natural sciences, life sciences, engineering or medicine were considered which are completely covered by the Science Citation Index (SCI). In addition, further 10 fields in the social sciences covered by the Social Science Citation Index (SSCI) and 5 fields referring to Arts and Humanities also covered by the Arts and Humanity Citation Index (A&HCI) were considered. For all broader field codes in SCOPUS, a concordance with the category codes of the SCI, the SSCI and the A&HCI was constructed. The investigation is limited to journal articles, and for some cases conference papers are analyzed as well. The searches were conducted in the in-house version of WoS, consisting of SCI, SSCI, A&HCI and Proceedings, and in the internet version of SCOPUS.

Looking at the development of publications in both databases, the absolute number of journal papers in SCOPUS is generally distinctly higher, at the level of 130% of the WoS publications (Figure 4). However, before 1996 there are no references of articles given in SCOPUS; only citation analyses after 1996 lead to reasonable results. In addition the number of publications recorded in SCOPUS in 1995 is distinctly lower than in 1996, implying a clear interruption of the general trend. In the area of natural, engineering, life and medical sciences (NELM), the publication numbers in SCOPUS are about 30% higher than those of the WoS. For the other publications – i.e. publications in the social sciences, arts and humanities – the numbers in SCOPUS are about 40% higher than in WoS. In any case, the number of publications in these other fields is distinctly lower than those in the natural, life, medical and engineering sciences. In both databases, the other publications represent about 10% of the total publications.

Figure 4: Journal Publications in SCOPUS and SCI in the Natural, Engineering, Life and Medical Sciences



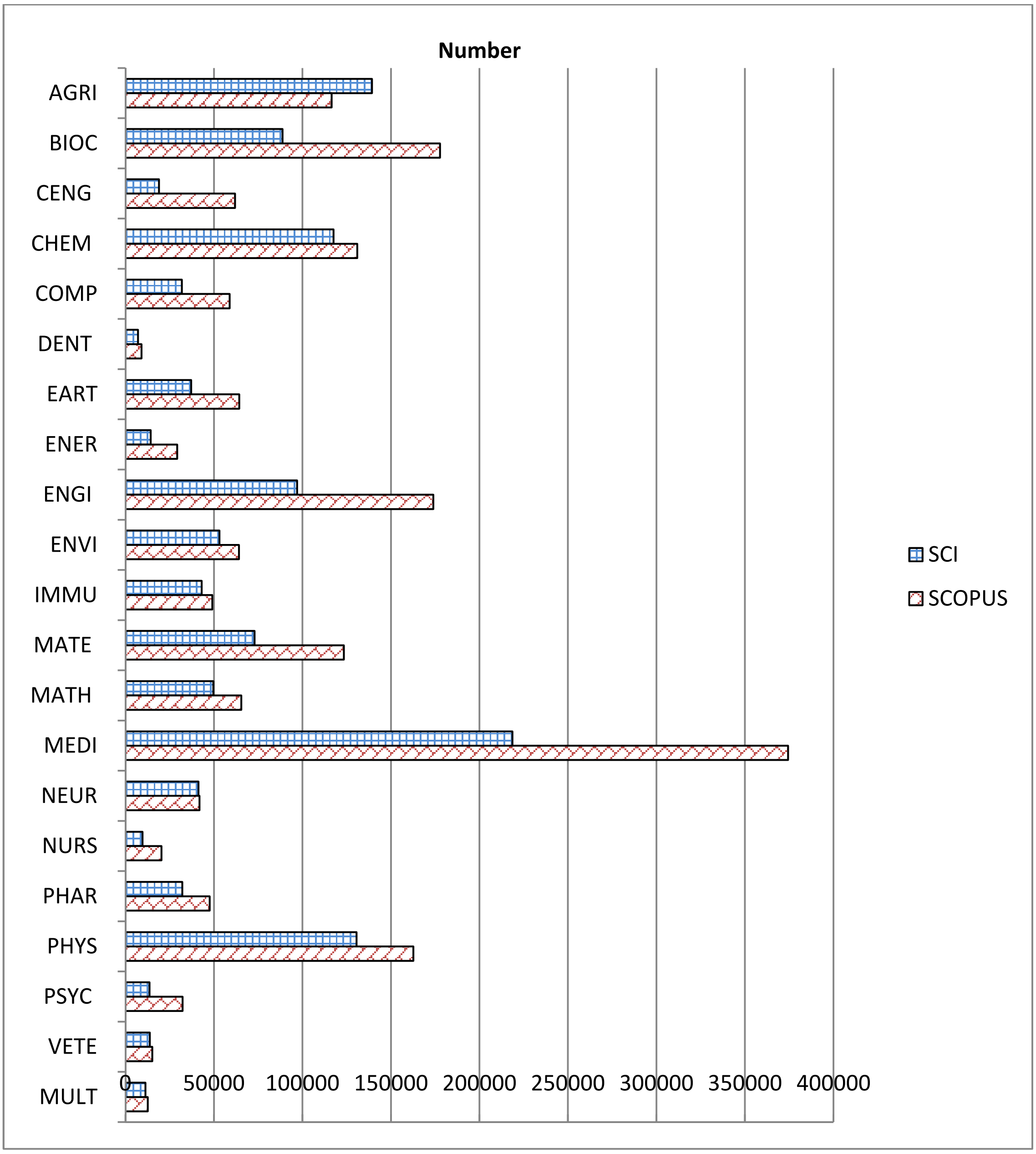
Sources: WoS, SCOPUS (internet version), searches and calculations by Fraunhofer ISI.

The generally higher number of papers in SCOPUS is, of course, also reflected in the number of recorded articles per field, but the distribution is not even, as documented in Figure 5 for the NELM fields. For instance, in the field BIOC (biochemistry, genetics and molecular biology), SCOPUS covers two times more publications than the SCI, in chemical engineering this difference is even 3.3. In contrast, the additional coverage in chemistry is only higher by the factor 1.1. A relevant point is that in engineering (code ENGI) which is a field insufficiently covered in the SCI, the number of articles in SCOPUS is higher by the factor 1.8, so that a substantial improvement can be determined.

A special case is agriculture (AGRI) where the number of journal articles in WoS is higher than in SCOPUS. However, this may be an effect of an unsuitable concordance between the SCOPUS code AGRI and the category codes in the SCI, as according to the SCOPUS documentation, the field covers different areas of biology in addition to agriculture. However, parts of biology are also included in the codes BIOC (biochemistry, genetics and molecular biology) as well as IMMU (immunology and microbiology), and the delimitations of the fields are not really clear.

Also in the non-NELM fields, the coverage of SCOPUS is broader than WOS. In particular, in the social sciences (except economics) and economics (incl. business economics), the number of publications in SCOPUS is substantially higher (Figure 6 and Figure 7).

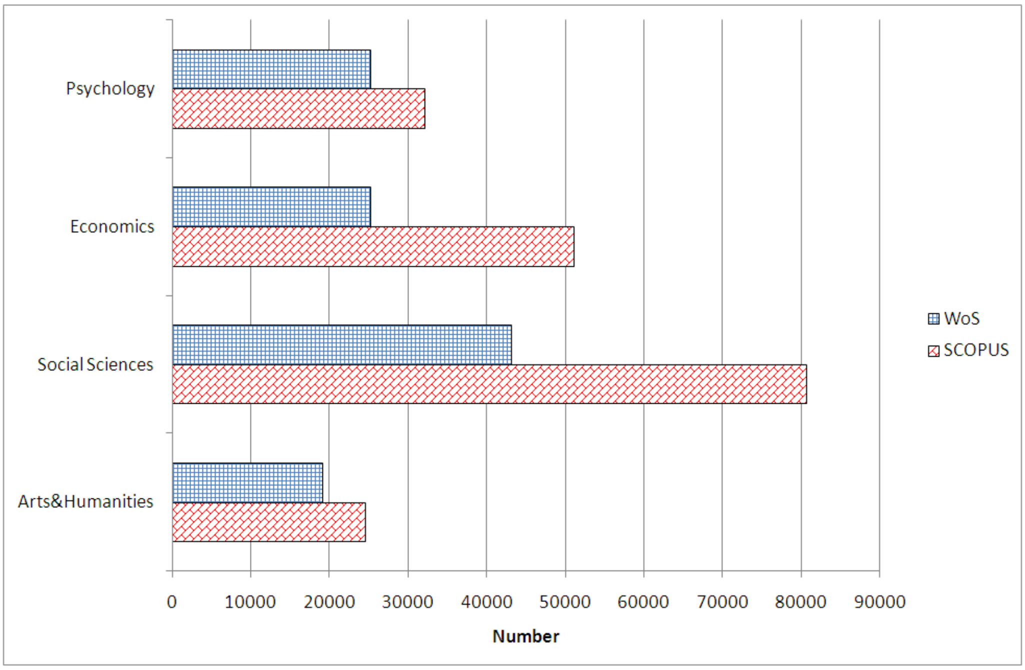
Figure 5: Journal Publications in Sub-fields of SCOPUS and WoS in the Natural, Life and Engineering Sciences, 2008



Sources: WoS, SCOPUS (internet version), searches and calculations by Fraunhofer ISI.

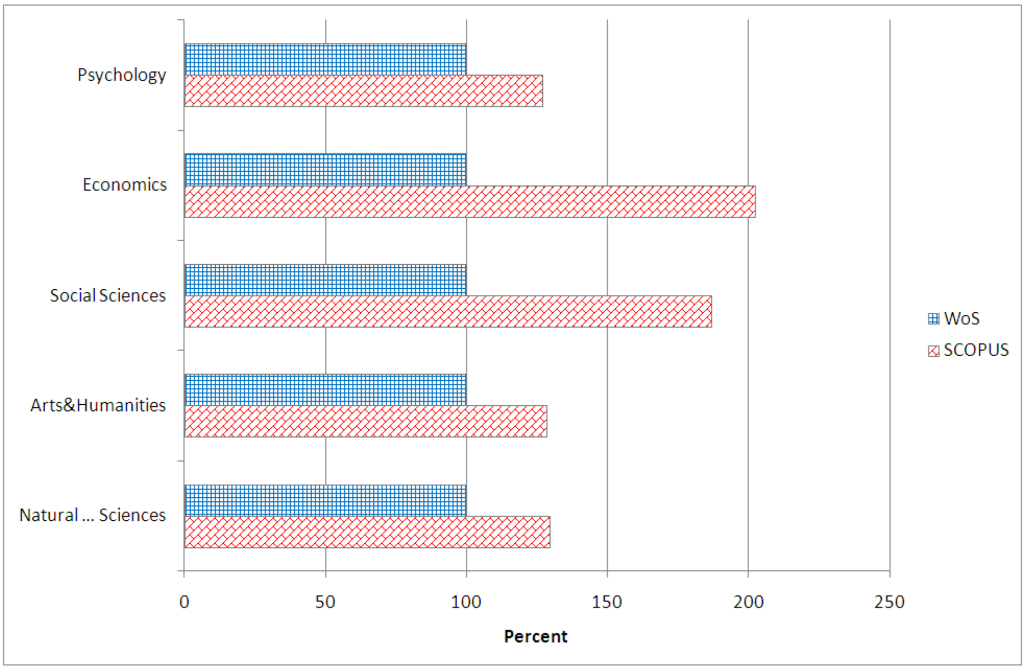
Field abbreviations are documented in Appendix A5

Figure 6: Journal Publications in Sub-fields of SCOPUS and WoS outside the Natural, Life and Engineering Sciences, 2008



Sources: WoS, SCOPUS (internet version), searches and calculations by Fraunhofer ISI.
Content of fields is defined in Appendix 5A

Figure 7: Journal Publications in Sub-fields of Science covered by SCOPUS in Relation to WoS, 2008



Sources: WoS, SCOPUS (internet version), searches and calculations by Fraunhofer ISI.
Content of fields is defined in Appendix 5A

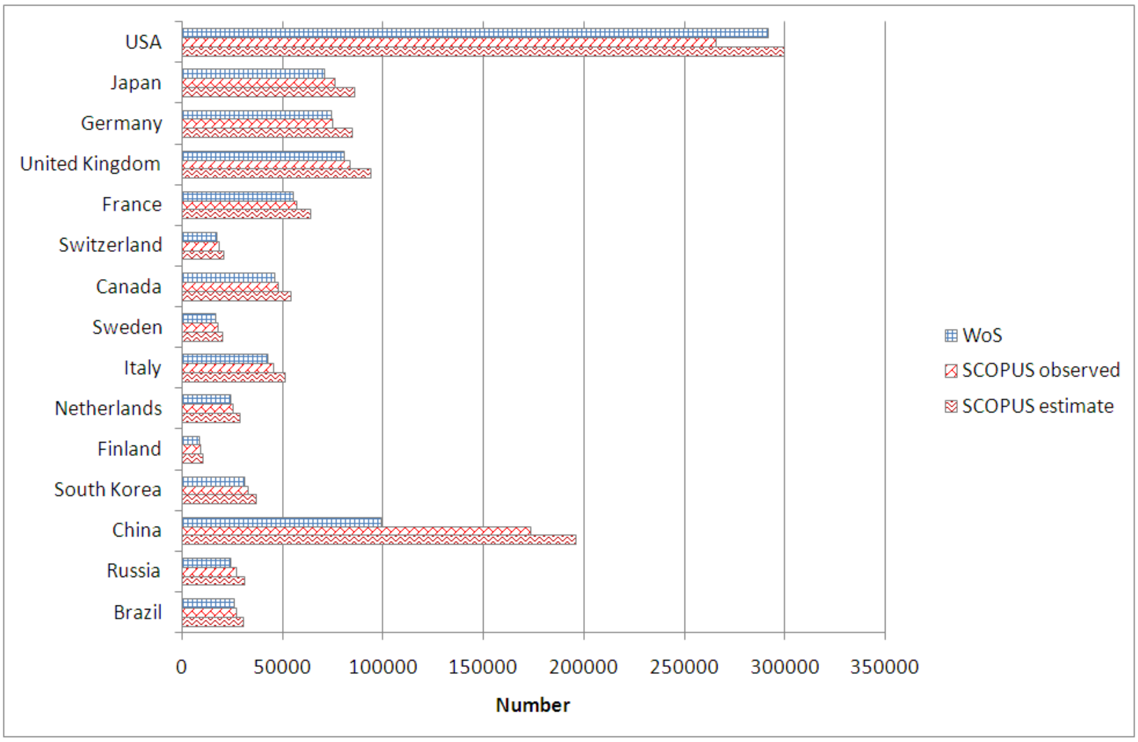
Looking at the coverage of countries, the additional papers in SCOPUS have a moderate effect on the established industrial countries. For instance, for France, 3% additional articles are included, for Germany 1%, or for Japan 7% (Figure 8). Among the industrial countries the United Kingdom profits with an additional 6% and the Netherlands with 6%. However, a substantial additional coverage is visible for China, with 75% of additional articles, or for Brazil with 4%. The latter observation can also be found for other South American countries. But for the USA the numbers diminish by 9%

However, the figures exclusively refer to database records, where a country of origin is recorded. In the case of WoS, almost all publication records offer a country of origin, whereas it is quite often missing in SCOPUS. All in all, about 15% of all SCOPUS records in 2008 have no indication of the country of origin. This finding is linked to the fact that various existing databases were integrated in SCOPUS which have no specific item for the country of origin, for instance, the database ECONLIT, and obviously the database producer has not yet filled in the missing fields. Therefore at present, it is only possible to make estimates about the real country coverage in SCOPUS, for instance, based on the assumption that all countries are affected at the same level. Then the share of additional papers in SCOPUS is higher than documented above, for instance for France 16% (instead of 3%) additional articles are included, for Germany 14%, for the USA 3% or for Japan 21%, for the United Kingdom 16%, the Netherlands 20%, or China 97% and Brazil 7% (Figure 8).

The different sub-fields of SCOPUS are affected at different levels. In NELM the share of records with missing country codes is 9%, in arts & humanities 47%, in social sciences 40%, in economics 21% and in psychology 16%. Thus the non-NELM fields are affected more severely.

Obviously, this estimate has to be improved. The USA seem to be affected by missing country codes more severely than others, so that in the version investigated, the total number of publications in SCOPUS is even lower than in WoS. In contrast, the figures for China are already quite high in the observed version and probably will not increase as assumed in the estimate. It will be necessary to supplement the missing codes based on the address information of the institution, and Elsevier has announced a new version for end of 2010 where the missing codes may be completed. Nevertheless, the coverage of countries in SCOPUS obviously is much broader than in WoS, but needs corrections.

Figure 8: Documented and Estimated Number of Publications by Author Countries in SCOPUS and WoS, 2008

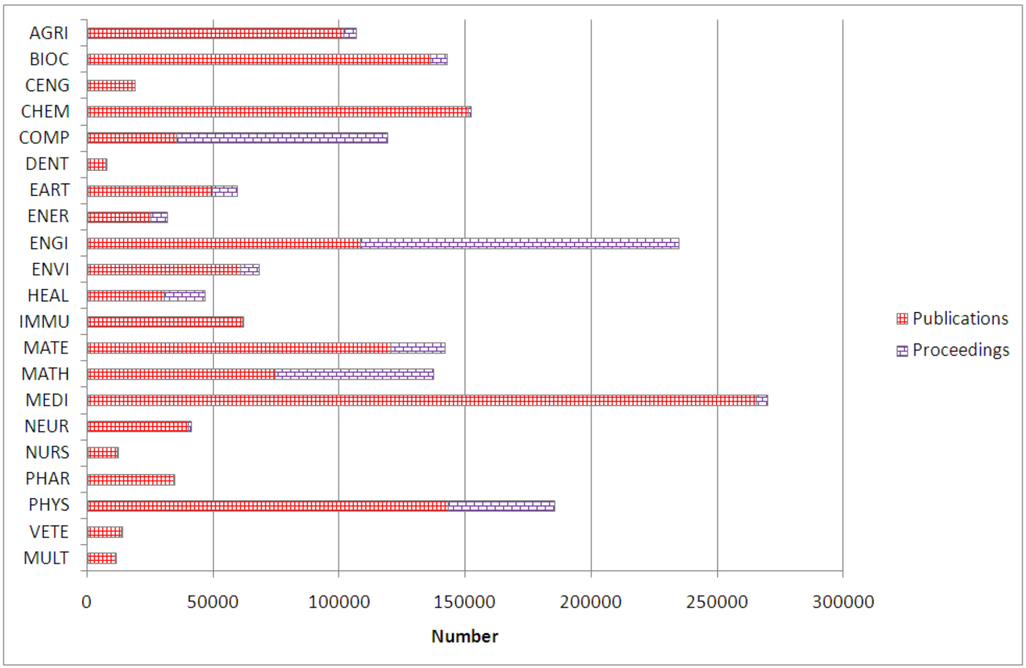


Sources: WoS, SCOPUS (internet version), searches and calculations by Fraunhofer ISI.

The further decisive question is the representation of conference papers in the two databases. In many fields, conference papers are considered inferior publications compared to journal articles with more careful referee procedures. Against this background, conference papers cannot be analyzed as to their citations or impact in the SCI. However, in fast moving fields, in particular in the computer sciences and engineering, conference papers are important contributions to scientific progress and are highly cited, as they are almost equivalent to journal papers.

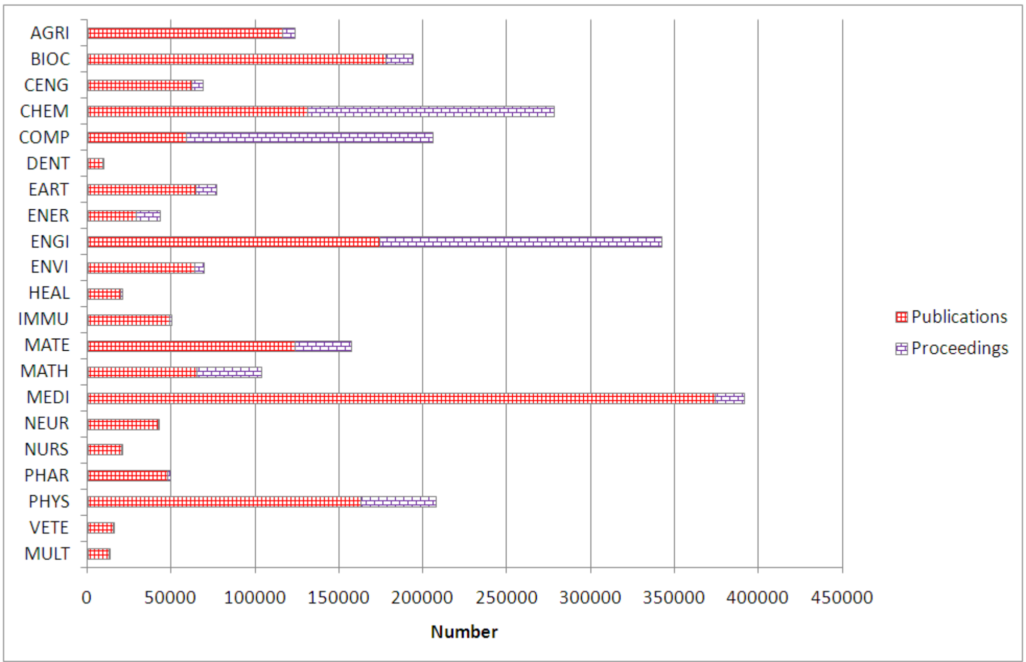
The computation of the journal and conference articles in the SCI shows that conference papers constitute only a minor part in most fields and are only relevant in computer sciences, engineering and mathematics (Figure 9). The same scrutiny for SCOPUS shows a similar pattern, but substantially higher shares of proceedings in chemical engineering (Figure 10). In the decisive fields of computer science and engineering, the absolute number of proceedings in SCOPUS is distinctly higher than in WoS, by 77% and 33% respectively. Furthermore, conference papers can be analyzed as to their impact in SCOPUS. SCOPUS offers substantial additional options in this regard.

Figure 9: Journal and Conference Publications in Selected Sub-fields of WoS



Sources: SCISEARCH (STN), WoS, searches and calculations by Fraunhofer ISI.
Field abbreviations are documented in Appendix A5.

Figure 10: Journal and Conference Publications in Selected Sub-fields of SCOPUS



Sources: SCOPUS (online version), searches and calculations by Fraunhofer ISI.
Field abbreviations are documented in Appendix A5.

It appears quite strange that some fields in WoS, in particular chemical engineering and chemistry, have a very low level of proceedings. This observation is obviously linked to the fact that our WoS-Version consists of four partial databases, SCI, SSCI, A&HCI and a proceedings file. In the latter, the proceedings referring to the three other areas are recorded. But in chemical engineering, for instance, no documents can be found in the proceedings file, but obviously various proceedings are integrated in the SCI and are classified as articles. So a finer analysis of the sources will be necessary to achieve an accurate picture. In any case, the number of publications, either articles or conference proceedings, in SCOPUS in the engineering fields is substantially higher than in WoS, even after such corrections.

To summarize, the comparison of the databases WoS and SCOPUS shows that SCOPUS has a broader coverage of threshold countries, in particular China, than the SCI. Furthermore, the coverage of articles in the computer sciences and in engineering is much more important than in WoS.. The further relevant difference of SCOPUS in comparison to WoS is the substantial inclusion of conference papers in the computer sciences and the various fields of engineering, linked to the possibility of an impact analysis, thus of citations of conference papers by other journal and conference papers. In consequence, SCOPUS enlarges the possibilities of bibliometric analysis, but is primarily complementary and less substitutional to the SCI.

A5 Appendix

Meaning of abbreviations for scientific fields in Figure 5, Figure 9 and Figure 10

AGRI = Agricultural and biological sciences

BIOC = Biochemistry, genetics and molecular biology

CENG = Chemical engineering

COMP = Computer science

DENT = Dentistry

EART= Earth and planetary sciences

ERER = Energy

ENGI = Engineering

ENVI = Environmental science

HEAL = Health professions

IMMU = Immunology and microbiology

MATE = Materials science

MATH = Mathematics

MEDI = Medical science

NEUR = Neuroscience

NURS = Nursing

PHARM = Pharmacology, toxicology and pharmaceutics

PHYS = Physics and astronomy

VETE = Veterinary science

MULT = Multidisciplinary journals

Definition of fields in Figure 6 and Figure 7

Psychology = Psychology (not psychiatry)

Economics = Economics, business, finance

Social Sciences = All social sciences except economics

NELM = All fields in the natural, engineering, life and medical sciences

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