operation is mainly in the fields in which the partner countries are particularly strong. Overall, co-patents in Germany are mainly in the field of chemistry, but there are relatively few in mechanical engineering, so that German companies are following the general pattern in these sectors.

These comments are based on the study by Frietsch and Jung (2009). The study also investigates:

- General trends and structures for transnational patent applications,
- Patent applications of small and medium-sized enterprises,
- Trends and structures for international co-patents.

C 7 SPECIALIST PUBLICATIONS AND THE EARNINGS OF SCIENCE

This section is based on the results of a study of international specialist publications.[117] The scientific potential of a country is a crucial basis for its technological performance. The contribution to technology development and knowledge-intensive services lies primarily in the education of qualified personnel, and their quality in turn is dependent on the ability of the researchers. Also, the results of scientific research form an important basis for technical development. The links between science and business are frequently indirect and not obvious, because there is often a time lag between the scientific activities and their effects in the economy.

It is difficult to measure scientific performance because the structures in the various disciplines can be very different. One method is the statistical analysis of the numbers of specialist publications and the frequency with which these are cited. In the natural sciences, engineering, medicine, and life sciences the database "Science Citation Index (SCI)" has established itself as the international standard.

Increasing integration of German science in the international community

The German share in international publications has fallen since the year 2000 by 12 percent, a trend which can also be observed for many other large industrialised countries. This development is attributable to the growth in the activities of emerging markets, which have meanwhile acquired a considerable significance. Their share of SCI-publications in 1990 was at 9 percent, but by the year 2000 this has increased to 15 percent, and by 2007 had risen further to 25 percent. Korea's specialist publications have been increasing appreciably since about 1992, after a long period of low publication activity. Since 1997, Korea has also experienced a massive growth in transnational patent applications. In the case of China, the publications trend changed in about 1996, and for patents in 1999. This demonstrates the indicator function of specialist publications for the availability of highly-qualified professionals who go on to induce a strengthening of the technological capability.

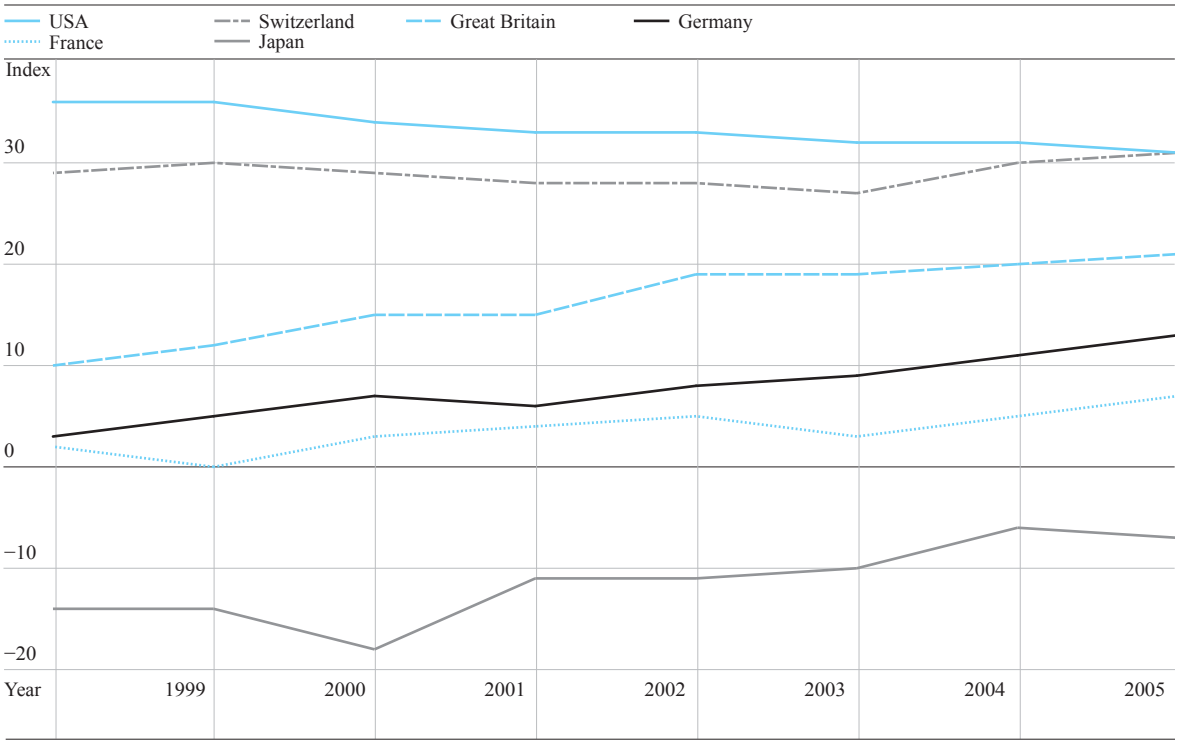
The relative citation frequency[118] is a central indicator for the scientific quality of publications, and here German scientists have maintained a mid-table position, slightly behind their American colleagues. Only Switzerland has an outstanding international position here.

The indicator "international orientation"[119] has for many years shown the orientation of German authors towards high-profile international journals and thus towards closer involvement in the international discourse, although in this case German scientists are following a general trend which is also apparent in other countries (Fig. 28). Switzerland, the USA and the Netherlands occupy the first three places for international orientation. In the cases of Switzerland and the Netherlands (Index-values of 31 and 27) this demonstrates their very intense integration in the international discussion, whereas in the case of the USA (Index 31) it is above all due to their direct access to American journals, which have a broad international readership and thus a considerable influence on the international discussion. However, the index for the USA is declining, and this reflects an upward trend for other countries.

German strengths in physics and medical engineering

For the analysis of publication activities according to subjects, it is usual to calculate specialisation indices, because the publication habits are very different in the various disciplines and therefore a comparison of ab-

International orientation of specialist publications for selected countries FIG 28



Indices: International orientation with reference to the global average: 0 = average, > 10 very much above average.
Source: SCI. Research by University of Leiden. Calculations by Fraunhofer ISI.

solute numbers could create false impressions. Specialisation indices show whether the share of a discipline in the publications of a country are above or below this share for the publications in the entire database of worldwide publications. The German authors are particularly strong in physics and the closely related nuclear engineering (Fig. 29). A further strength is medical engineering. This structure has remained unchanged in recent years. All three fields show above-average scientific performance, expressed by the relative citation frequency and the international orientation.

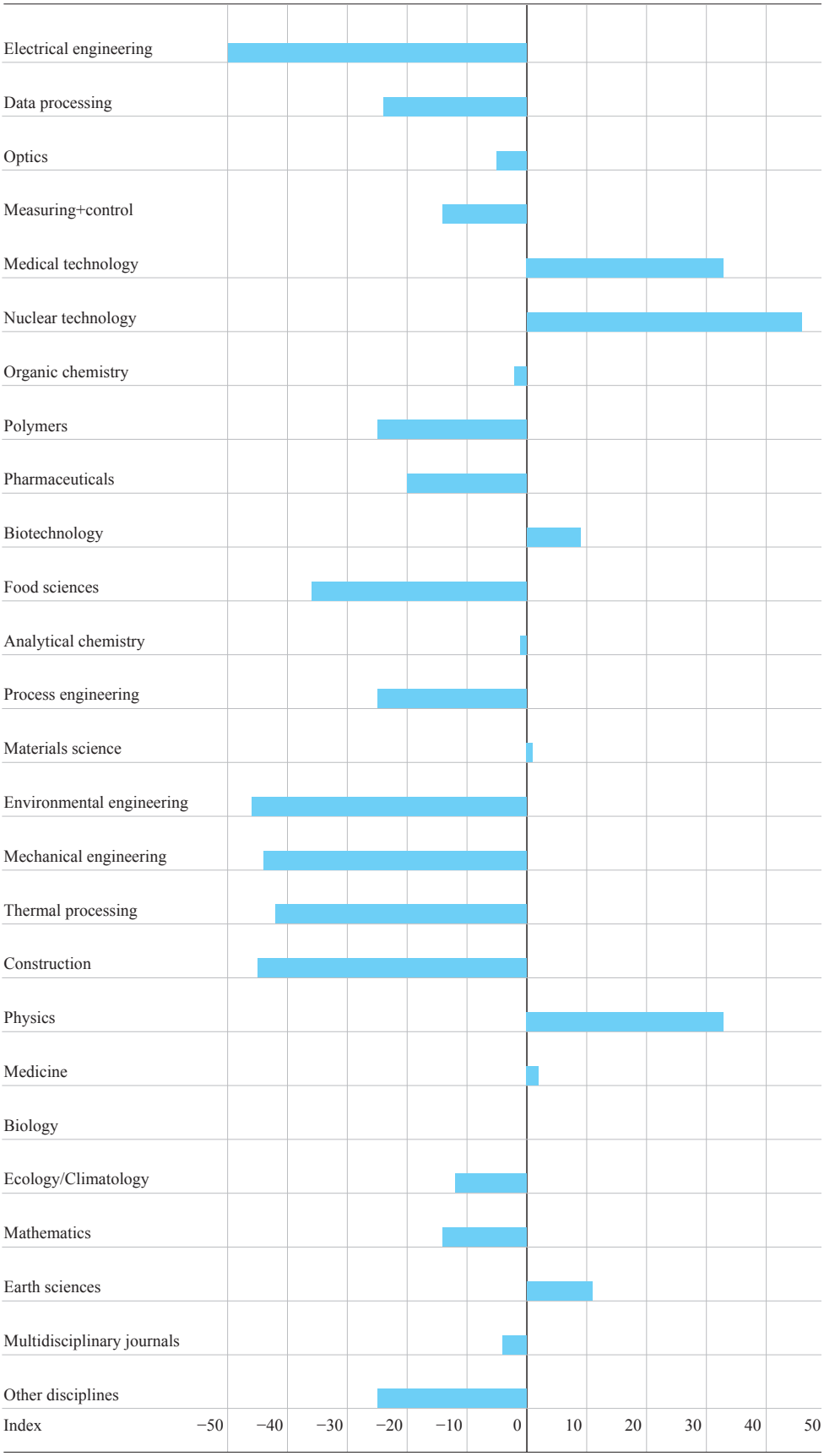
In an international comparison, publication activities are below average for data processing, which also has less weight in the economy. A noticeable contrasting feature is that the German specialisation index for biotechnology is slightly above average, and the scientific performance is also above average. Here the science is better than the economy. The negative indices in the various sub-disciplines of engineering are an artefact and are based on the fact that the relevant publications in other languages apart from English are not covered at all adequately. However, it is possible to conclude that German engineers should become more strongly involved in the international discussions.

Important contribution of start-up companies to specialist publications

Companies frequently protect the results of their research by patents, but they rarely publish in scientific journals. Only 6 percent of all German SCI-publications are from companies. An important goal of such publications is to signal competence to the scientific institutions and to open up channels for cooperation. The specialist publications of companies reflect the results of strategic basic research which offer a high potential for fundamental innovations. The publication activities of large German companies have been stagnating since the start of the 1990s, but those of small and medium-sized enterprises have been growing constantly; meanwhile they generate more publications than the large companies (Fig. 30).

The majority of the publications of small and medium-sized companies come from small technology-oriented enterprises which are still in an early phase of their development. Medicine and the life sciences are particularly dynamic fields. These results demonstrate a structural change over the past 15 years, during which period large companies have reduced their central research activities and have increased

FIG 29 **Specialisation of Germany based on publications in Science Citation Index 2007**



Indices: Specialisation with reference to the world average: 0 = average, +20 considerably above average.
Source: SCI. Research and calculations by University of Leiden (CWTS). Calculations by Fraunhofer ISI.

applied research in the specialist departments. They then observe the activities of start-up companies and buy these up when they have shown themselves to be successful. A division of labour has established itself in which the start-up companies play an important role. More than 60 percent of publications of small, young companies are written in cooperation with universities, and a good quarter with foreign companies. The small companies are thus clearly linked to international research developments. Co-publications document close cooperation in scientific research, because both sides have to make a relevant contribution. In the case of young companies the founders frequently come directly from scientific institutions and continue to cooperate with their former colleagues.

When considering company publications in terms of disciplines, engineering comes out top in absolute numbers, followed by medicine, natural sciences, and life sciences. This result may seem surprising at first, but it can be explained by the considerable importance of basic research in fields such as materials and surface engineering, sensor technology, or communications technology. The activities of small and medium-sized companies are markedly higher than those of the larger companies in engineering in particular. In contrast, large companies currently equal the absolute levels of small and medium-sized companies in the life sciences. This is attributable in particular to companies such as Quiagen or Miltenyi, which were founded in the 1980s and which meanwhile have considerably more than 500 employees. In addition to the absolute numbers, the growth dynamic of publications of small and medium-sized enterprises is also remarkable, and is much higher than that of large companies in all sub-disciplines (Fig. 31).

These results illustrate the considerable potential of technology-oriented company start-ups for a structural shift of the economy towards cutting-edge technologies. The presentation here touches on the key results of a study by Schmoch and Qu (2009), which also considers:

- Trends and structures of scientific performance in an international comparison,
- Specialist publications of German companies, in particular SMEs,
- Trends and structures of specialist publications from emerging markets.

PRODUCTION, VALUE CREATION AND EMPLOYMENT C 8

The structural change of industry and services over the past two decades can conveniently be divided into three periods:

- The 1990s, the second half of which was marked by a global upswing in the economy,
- A weak economic period: 2000 – 2003,
- An upswing: 2003 – 2007.

The following statements are based mainly on data through until 2007. The developments in 2008 suggest that 2007 marks an economic highpoint. This is reflected meanwhile in considerably lower growth predictions for 2008 and 2009.

Research- and knowledge-intensive sectors as a motor for the economic development in Germany

In Germany, above-average value-creation profits and job creation in 'industry' are above all attributable to the research-intensive sectors.[121] This accounts for almost 80 percent of the real growth in production in the manufacturing sector between 1995 and 2007. However the variations in production due to economic fluctuations since the 1990s have also become stronger in the research-intensive sector.

In the cutting-edge technology sector, new, fundamental technologies are frequently developed, and in many cases growth expectations play more of a role than the economic situation. Therefore when the economy was weak there was only a slight dip in production in the cutting-edge technology sector, soon followed again by strong growth.

The high-value technology sector picks up newly created technological possibilities, but reacts markedly to cyclical signals. Thus the stagnation in this sector lasted until 2003, and the following growth period was less dynamic than in cutting-edge tech-nology. The development in high-value technology was determined in particular by stable growth of the car makers and their suppliers as well as some branches of mechanical engineering. Other branches of mechanical engineering only experienced strong expansion in the upswing beginning in 2003.