The situation is more varied in the research- and knowledge-intensive sectors. In the research-intensive manufacturing sector there have hardly been any changes in the numbers of companies in the USA, Germany, France, and Great Britain. In the knowledge-intensive services, Germany was able to keep up with the international trend of increasing numbers of companies through until 2000. But from 2001 the number of active companies stagnated, whereas they continued to increase in Great Britain and France. In an international comparison, the start-up activities in Germany have four special features:

– The company dynamic is very low. Both the numbers of start-ups and of closures are lower in relation to the overall numbers of companies than in most other countries.
– The structure of the start-up activity is less strongly directed to research- and knowledge-intensive sectors of the economy than in the other highly developed countries.
– The development of company start-ups over time is relatively weak, in particular for knowledge-intensive services.
– Nevertheless the number of companies has developed more favourably than in the other countries, because the low rate of start-ups has been compensated for by a low rate of closures.

It is positive that the number of companies has increased more in Germany than in other countries. However, from the point of view of promoting innovation, the low number of newly founded companies is relevant. The innovation pressure on existing companies is lower, fewer innovation impulses are provided by start-ups, and fewer innovation ideas are tested for their acceptability and market relevance. In Germany the barriers faced by new companies wishing to enter markets are higher by international standards, but the established companies then receive better support.

D 6 EDUCATION AND SCIENCE

The structural change in Germany over the past decade towards a research- and knowledge-intensive economy has consequences for the demands on the qualifications of the workforce. There is a growing need for highly qualified personnel, in particular graduates from higher education, who play a key role in successful innovation. This is the case for research and development, where the demand is mainly for natural scientists and engineers, as well as for the knowledge-intensive services, for which other graduates are also required. This section addresses aspects of education which are particularly relevant in the context of research and innovation.[91]

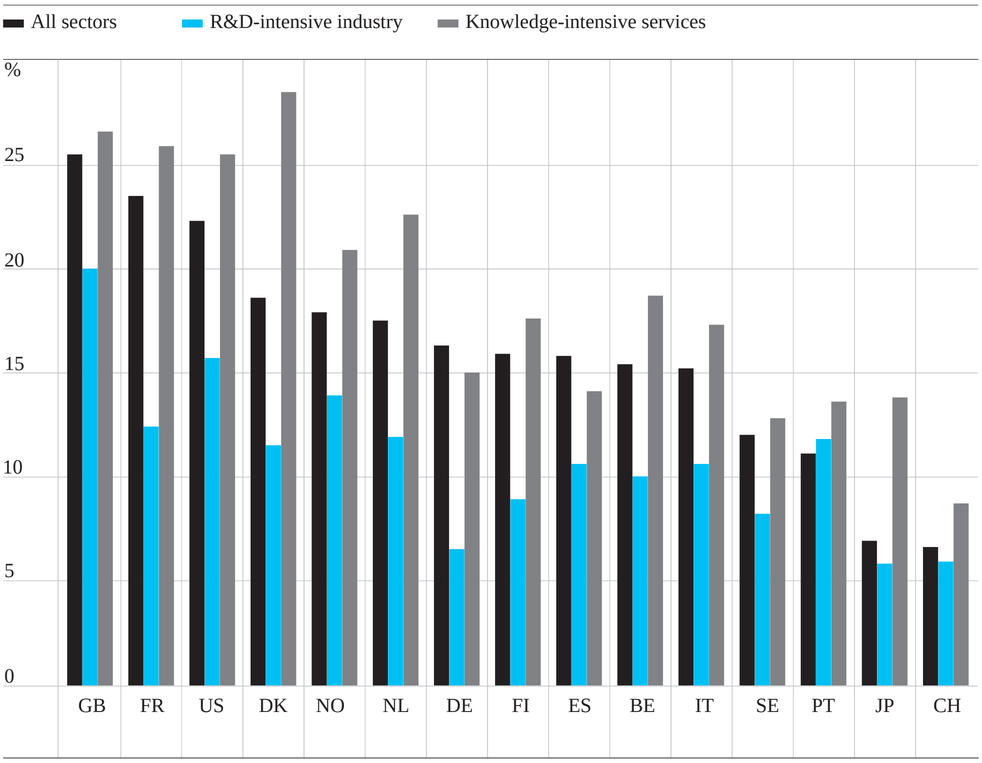
Increasing numbers of graduates due to knowledge intensification

In 2006, some 1.85 million graduates were working as employees in the commercial sector in Germany, with 682 000 natural scientists and engineers, and about 1.2 million graduates in other disciplines. About three-quarters of each group were employed in knowledge-intensive sectors. The numbers are even higher if the total workforce is considered, because in particular in the services sector many graduates are self-employed. Whereas almost 60 per cent of natural scientists and engineers work in the manufacturing sector, some 70 per cent of other graduates are employed in the services sector. More than a third of graduates in the commercial sector are thus natural scientists or engineers; the demand in this sector is particularly high.

A steadily increasing proportion of the employees in the commercial economy are graduates, and in knowledge-intensive sectors, the percentages are on average four or five times higher

Company turnover in selected countries

FIG 20



2004 or the last available year.
Source: Eurostat, U.S. SBA, INSEE, Statistical Office of Japan, ZEW. Calculations by ZEW.

than in other sectors. This increased demand for qualified personnel in knowledge-intensive sectors also extends to include the middle strata of the workforce vocational training.[92]

The change in the number of graduates can be divided into three components:

- The *trend effect* explains that part of the change which is due to the state of the economy, i. e. economic growth or stagnation.
- The *structural effect* results from the changes in the structure of the economy to knowledge-intensive sectors.
- The *knowledge intensification effect* reflects the increased demand for qualifications within the sectors.

A longer-term consideration shows that the key impulse for the employment of graduates comes from the structural change and in particular from the knowledge intensification (Figure 21). This means that within the knowledge-intensive sector, as in the rest of the economy, the demand for graduates is increasing continuously. From 1996 to 2006 this demand grew by an additional 345 000 labour force. Of these, 22 per cent were in the R&D-intensive manufacturing sector, 54 per cent in knowledge-intensive services, and 24 per cent in the other commercial economy.

High demand for graduates due to growth in the knowledge-intensive sectors

The shift towards a knowledge-intensive economy had its greatest effect at the end of the 1990s. With the collapse of the New Economy and the subsequent recession, knowledge-intensification became more important. Since there are currently signs of an increased orientation towards knowledge-intensive sectors, a demand can be anticipated for 40 000 to 50 000 additional graduates (structural effect), not yet taking account of economic growth and the need to replace retired personnel.

Additional demand for graduates due to demographic change and increased research and development

Under existing conditions, demographic effects such as the ageing of the society and shrinking age cohorts will of themselves lead to an increased demand to replace qualified personnel. But with relatively fewer graduates available, Germany is already experiencing shortages of natural scientists and engineers as well as computer scientists. This can slow down or even stop the process of knowledge intensification, and can act as a constraint on innovation and growth.

The three-percent target formulated as a policy goal in the Lisbon Strategy aims at a considerable expansion of research and development activities. This will require more highly qualified personnel, including scientists and engineers and also qualified co-workers for concomitant services, in addition to more skilled labour at the medium level. The demands on the universities and the institutions of vocational training will therefore increase massively.

Growing shortage of qualified personnel in the next decade

It is difficult to quantify the demand for specialists, the available supplies and the resultant shortages, because this involves making a series of assumptions about future developments, for example relating to future economic developments, the demand for graduates, the rate of knowledge intensification and the structural shift towards services, and the numbers enrolling and graduating from higher education institutions. In a study in 2007, three options were considered on the basis of conservative assumptions, with changes in employment through to 2014 of -2.5 per cent, ± 0 per cent, and +2.5 per cent. Even with a decline in employment, there would be an average annual shortfall of 3 000 engineers and 19 000 other graduates, and with an increase in the level of employment shortfalls are to be expected of 12 000 engineers and 50 000 other graduates.[93] For the growth option, this leads by 2014 to an accumulated shortage of some 95 000 engineers and 397 000 other graduates. These figures show that unless counter-measures are adopted there will be serious problems with the supply of specialists on the labour market.

In another study, also carried out in 2007, further options were investigated, taking into consideration the demographic development, the rate of unemployment, the transfer from vocational training to universities, and the introduction in Germany of bachelor's and master's degree courses.[94] In addition to university degrees, other educational and training qualifications were also taken into account, and the periods 2003 to 2020 and 2020 to 2035 were considered. The results obtained were in effect similar to those of the study first mentioned, in particular relating to the future shortages of natural scientists and engineers.

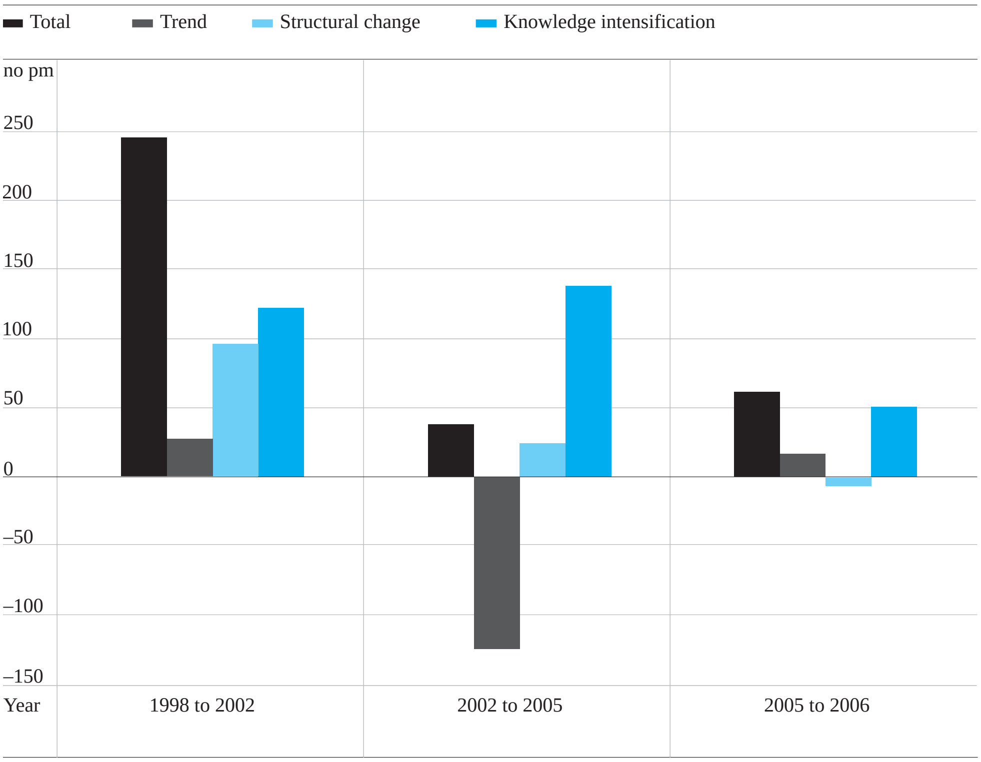
More new students enrolled in 2007

Over the past decade, numbers of new students enrolling for sciences and engineering courses increased considerably through until 2003 – with the exception of computer sciences (Figure 22). With increasing numbers of graduates at the secondary level entitled to access to universities, a continued increase was expected. Faith was placed in the attractiveness of the shorter new bachelor's degree courses and on the growing demand for graduates (much discussed in the media), particularly for computer scientists, engineers and natural scientists. However, since 2003 there has been a continual decline in the numbers of new students,[95] in total by 5.4 per cent between 2003 and 2006, and in mechanical engineering, electrical engineering and computer sciences by 10 per cent, 22 per cent and 13 per cent, respectively. In 2007, the numbers of new students increased again by four per cent over 2006. Although this growth is by no means enough to compensate for the deficits which have accumulated in recent years, it could mark the start of a reversal of the previous downward trend.

In the last years, the lengths of secondary education has been shortened by one year. This will mean that in one academic year schools will have two groups of students with either formerly long or reduced education lengths sitting their final school examinations at the same time implying an above average number of high school graduates for a certain period. This surplus supply will extend over the period of 2009 to about 2015, as the German *laender* did not introduce this new scheme concomitantly. It remains to be seen

Changes in the employment of graduates by components

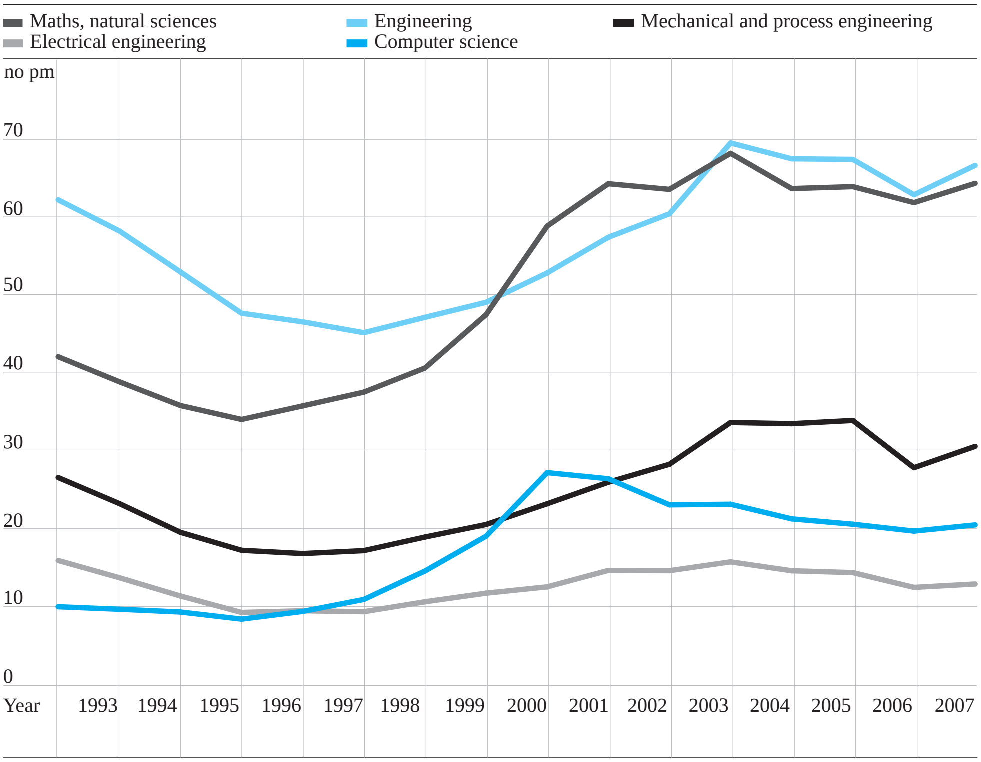
FIG 21



Source: Bundesagentur für Arbeit, Statistik der sozialversicherungspflichtig Beschäftigten (Statistics of the employees liable to social insurance). Calculations by NIW.

New students of selected subject groups in engineering and science in Germany

FIG 22



2007 extrapolated.
Source: Studentenstatistik, Statistisches Bundesamt. Calculations by HIS. Calculations by Fraunhofer ISI.

how the universities will cope with this 'surge'. In subsequent years the demographic development will mean that there will then be a sharp decrease in enrolment numbers, even with increased participation rates, so that the universities will have to be careful with steps to temporarily expand their capacity.

Large numbers of drop-outs in science and engineering

The number of first-year students who will go on to be available as graduates on the labour market depends on the progress of the individual study process. In particular the numbers dropping out of university without a degree provide an indication of the inefficiency of the German system of higher education. In 2004, 24 per cent of all university undergraduates dropped out, and 28 per cent of those studying mathematics, computer science, natural sciences or engineering subjects. Every year at least 7000 engineering students and more than 13000 natural science students drop out before qualifying.[96] This is almost half the increase in the numbers of graduates in the commercial sector overall in 2006 with reference to 2005. The total number of dropouts for all subjects in 2002 was more than 86000, which is even greater than the annual increase in graduates in the entire German economy. In other words, the number of students dropping out of university is greater than the additional numbers entering into employment. The total loss (drop outs plus students changing to another subject) in engineering subjects in 2004 was -35 per cent - and in electrical engineering (-49 per cent) and in mechanical engineering (-44 per cent) it was particularly high. It is still unclear whether the introduction of bachelor's and master's degree courses will lead to the intended reduction in these high levels.

Growing number of vocational training agreements

The increased demand for skilled personnel in knowledge-intensive sectors of the economy not only applies for those with higher education qualifications, but also in the middle organisational layers for employees with vocational qualifications.[97] In particular in the rapidly growing services sectors there are increasing vocational training activities.[98] The importance of the combination of theoretical and practical vocational training has obviously been recognised in the young, knowledge-oriented sectors of the economy. The number of newly concluded vocational training agreements has risen from 550000 in 2005 to 576000 in 2006 – an increase of 4.7 per cent. A further increase is now also expected for 2007. However, this increase of people in vocational training will soon be counteracted by the drop in the numbers leaving school. According to current estimates about 100000 fewer school-leavers will be available for the (vocational) dual training system in 2015.[99] There are already signs of this decline in numbers, particularly in East Germany.

Participation of the knowledge-intensive services sector in vocational training

The vocational trainees in the knowledge-intensive sectors of the economy account for 30.2 per cent of all trainees, which is less than would be expected on the basis of the number of employees in these sectors as a proportion of the total workforce (Figure 23). Overall, however, the so-called dual training system is also extremely relevant for the service sector, including the knowledge-intensive services.

Comparing the development of vocational training and employment in the knowledge-intensive sectors of the economy between 1999 and 2005, then measures to boost vocational training activities can be identified in particular in the manufacturing sector. Whereas the number of employees fell by 2.3 per cent, the number of trainees rose over the same period by almost eight per cent. The most growth was in mechanical engineering (nine per cent), and in vehicle construction (19 per cent), that is in the sectors in which production and foreign trade are particularly successful. At the end of 2005 a total of 24 per cent of companies were actively involved in vocational training, in the R&D-intensive manufacturing companies it was 38 per cent, and in the knowledge-intensive services 26 per cent. Therefore in the knowledge-intensive economy the rate of involvement in vocational training is above average.

Scientific publications as indicators of performance

The scientific potential of a country provides an important foundation for its technological potential. The contribution to the development of technology and to the provision of knowledge-intensive services consists in the training of qualified specialists, and their quality depends to a great extent on the performance of research. The results of scientific research also provide an important foundation for technological development. The links between science and business are often indirect and less obvious, because of the span of time between the scientific activities and their technological implementation.

Scientific performance is difficult to measure, especially because the structures in the individual disciplines can differ widely. A helpful approach has proved to be the statistical analysis of specialist publications, in particular using the Science Citation Index (SCI). The German share in worldwide publications has been declining since the year 2000, an observation which also applies for many other large industrialised countries (Figure 24). This development is due to the rapid growth in the activities of the industrialising countries, the effect of which is becoming increasingly noticeable.

Scientific regard is a citation-based key indicator for the scientific quality of publications,[100] and here German scientists have maintained an upper-middle position in the ranking lists, only slightly behind their American colleagues. In an international comparison, Switzerland has an outstanding position.

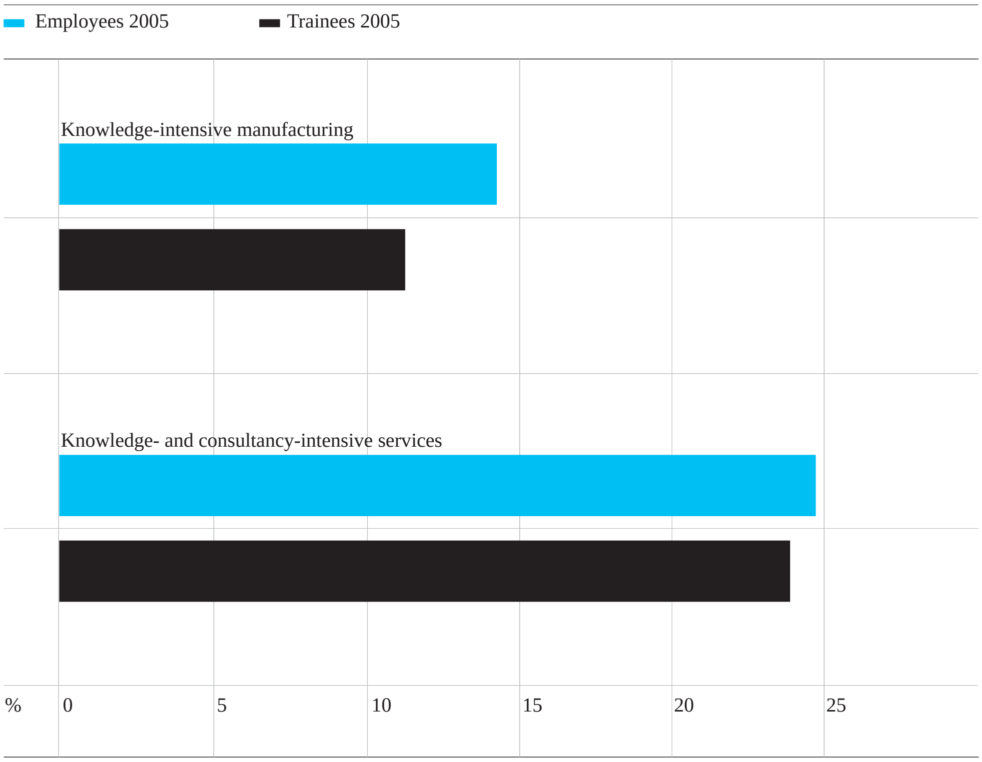
Taking the international alignment, a further citation-based indicator, German authors have increasingly been participating in the international discussions, and publishing in prominent international journals. This trend has probably also been due in no small part to the increased attention paid to publication- and to citation-based indicators. The numbers of publications in international, peer-reviewed journals and the frequency of citation are playing an increasingly important role in Germany, both for the evaluation of scientific institutions and also for appointments and career decisions.

Concentration of German publications in specific fields

This improved integration of German research results in the international scientific community is positive. At the same time, however, careful monitoring is needed to observe any unintended consequences in the medium-term, e. g. a loss of specialisation of Germany in specific research topics. For the indicator of international alignment, Switzerland again has a leading position and is far ahead of Germany. A comparison of citation indicators for Switzerland and Germany clearly demonstrates that the scientific activity in Switzerland covers almost all fields, whereas this is not the case in Germany.

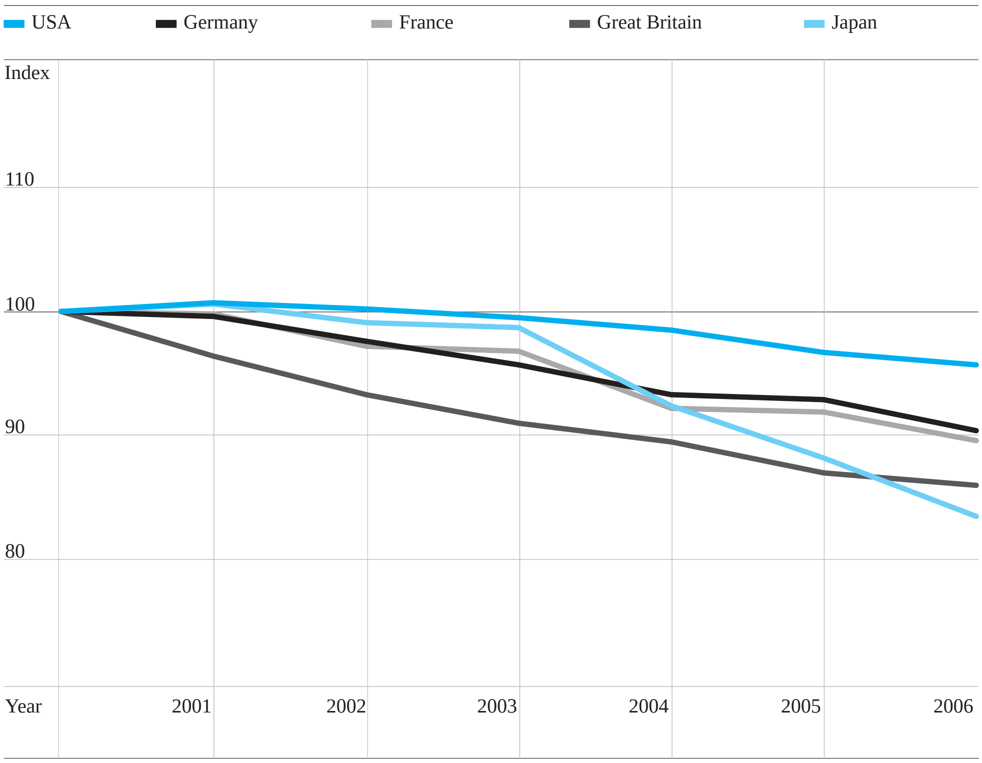
International co-publications have increased in numbers over the past 15 years. This applies also for German authors and in particular for joint activities within the EU member states.

FIG 23 **Proportions of employees and trainees in knowledge-intensive sectors with reference to the overall economy, 2005**



Source: BIBB, IAB. Calculations by BIBB.

FIG 24 **Shares of selected countries and regions of all publications in the SCI**



Index 2000 = 100.
Sources: SCI, University of Leiden (CWTS). Calculations by Fraunhofer ISI.

Co-publications are primarily important in the natural sciences and the life sciences, with engineering and medical science showing higher growth rates and gradually catching up. The most important partner country for German authors remains the United States. However, the total number of co-publications with authors from other EU member states is greater than for the USA and shows clearly higher growth rates. To this extent, the European Research Area has become a reality, at least from a German point of view.

A closer analysis of the publication partners shows that the scientific cooperation between Germany and the other large EU member states, in particular Great Britain, continues to be very important. The role of the smaller countries from the EU-15 is growing, but in absolute terms even their combined importance remains well behind Great Britain and France.

The importance of the new EU member states from Eastern Europe has been increasing since the mid-1990s. Their EU membership had led to a considerable increase in the range of their cooperation partners, and the specific orientation towards Germany has diminished. The EU is therefore growing closer together in the scientific sector. The cooperation patterns of European countries with one another are broadening and are becoming more and more similar. This shows that the European Research Area has not only become an important factor for scientific performance from a German perspective.

Conclusion of the detailed report on research and innovation in Germany

Overall, the review shows that Germany occupies a good position in many areas of research and innovation. However, in recent years the international competition has become stronger, so that Germany will have to make increased efforts in order to maintain its current level.