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.

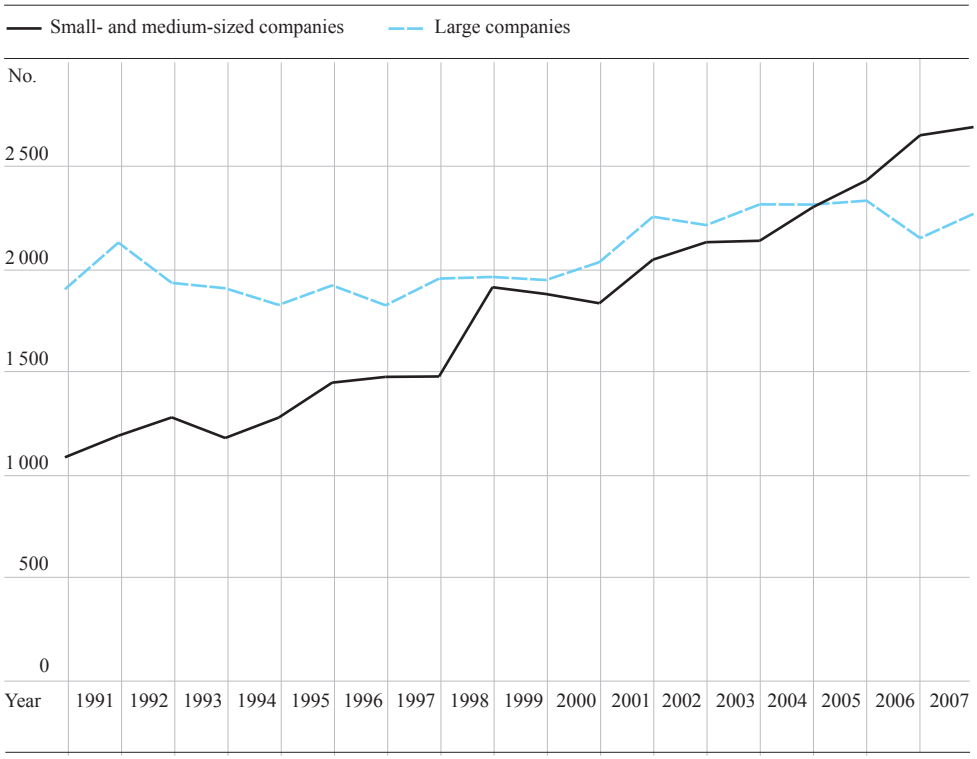
Research- and knowledge-intensive sectors as a motor for the economic development in Germany

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.

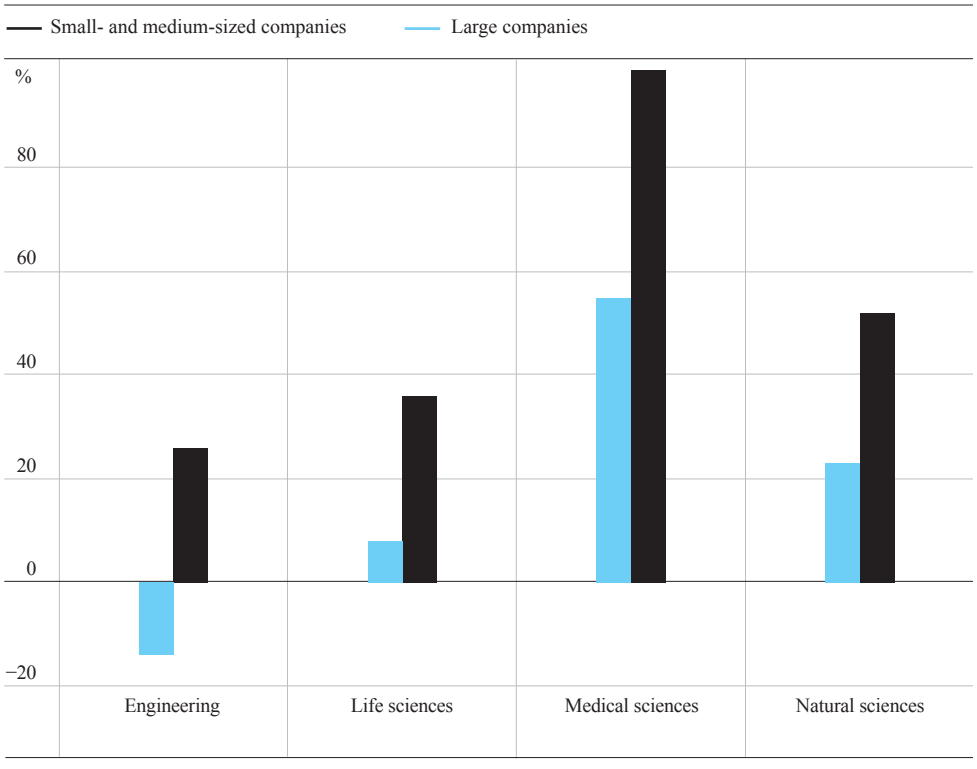
The high-value technology sector picks up newly created technological possibilities, but reacts markedly to cyclical signals. Thus the stagnation in this sector lasted until 2003, and the following growth period was less dynamic than in cutting-edge tech-nology. The development in high-value technology 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.

FIG 30 **Numbers of scientific publications by companies of various sizes in Germany**



Source: STN (SCISEARCH). Research by Fraunhofer ISI.

FIG 31 **Increase in scientific publications of companies in Germany 2000–2007**



Source: STN (SCISEARCH).

In the non-R&D-intensive manufacturing sectors the economic downturn impacted earlier and the subsequent growth in the upswing was weaker.

Clear losses to be expected in the automotive sector and mechanical engineering, with further growth in cutting-edge technology

For 2008, overall growth is taken to have been 2 percent, with research-intensive manufacturing sectors achieving more than 3 percent, once again performing much better than the other sectors. However, the automotive sector has lost the function as engine of growth in industrial production which it held for many years.

It can be assumed that the annual average industrial production for 2008 is one percentage point down from the previous year. For 2009 a decline in industrial production is expected over a broad front, with the non-research-intensive manufacturing sector being more severely affected than the research-intensive sector. However, the latter is also expected to experience a decline. The associations representing the Computer/Media technology sector are expecting to see a halving of their growth potential, but are still aiming to achieve the clear growth of their market.[121]

Considerable increase in productivity in the R&D-intensive sector. Uncoupling of production volumes and employment

In 2007, the R&D-intensive sector employed 48 percent of the overall manufacturing workforce.[122] Since the mid-1990s, employment levels in this sector have been declining, interrupted only by a short growth period between 1997 and 2001. However, this is much less severe than in the non-R&D-intensive manufacturing sectors (Fig. 07 in B 5).

In cutting-edge technology, the manufacturers of IC-equipment and components as well as producers of active pharmaceutical substances have been cutting back employment levels to a considerable extent since 2001. There have been positive employment developments in medical technology, weapons/munitions, advanced instruments[123] and in aircraft and spacecraft construction. Despite an above-average expansion of production (Fig. 33), employment in the research-intensive manufacturing sector is also declining in the medium-term. The differences between developments in growth and employment reflect the considerable advances in productivity. This rapid development is the result of international competitive pressure, which is particularly intense in the R&D-intensive sector.

Strong competition in cutting-edge technology

In particular in the 1990s, companies in the research-intensive manufacturing sector concentrated on their core competence and increasingly outsourced performances to the non-research-intensive manufacturing sectors, the services sector and to companies in other countries. In the cutting-edge technology sector, the enormous increase in productivity of more than 11 percent p.a. during the upswing from 2003 to 2007 explains why there was strong growth in production coupled with stagnating employment levels.

However, viewing cutting-edge technology overall, while there are considerable increases in production, revenue developments are now weaker. This is above all due to the drop in prices in the IC and electronics sector as a result of increasing international competition and the advances made by the emerging markets, whose industries can operate with much lower labour costs for adequately qualified personnel.

The cutting-edge technology sector is now more than ever a driving force for the economic development of Germany. It provides important impulses for the high-value technology sectors and the services sector. It should also be taken into account that in Germany most employees in cutting-edge technology in 2007 were working in the sub-sectors “Advanced instruments”, “Special pharmaceuticals” and “Medical equipment”.[124] The segments “Electronic components”, “Entertainment electronics” and “IC technology”, which are under particular price pressure, are less important here. Germany has a good status in research and development in both the industrial and academic sectors, so that it is well, but not excellently positioned to be able to cope with international competition in the cutting-edge technologies sector.

Continued employment growth in the services

Due to the close ties between the manufacturing sector and the services, employment effects are not always

direct in the former, but are felt to a considerable extent indirectly. In particular production and employment in research-intensive manufacturing sectors and the corresponding activities in the services sector can only be viewed in combination. While the longer-term observation of the development of value-creation in the manufacturing sector shows that this is highly cyclical, it went through a period of stable growth at the beginning of the 1990s both in the knowledge-intensive services sector and the non-knowledge-intensive services sector (Fig. 33). And although employment in the manufacturing sector as a whole declined, in the longer term the knowledge-intensive services sectors have opened up more employment opportunities than the other services sectors (Fig. 07 in B 5 and Fig. 32).

When assessing the knowledge-intensive services it must be borne in mind that sub-sectors can have very different significance in different countries. In Germany, "Health" is a particularly important sub-sector in terms of the labour input. It is followed by company-oriented services, a large part of which are non-technological consultancy. The service sectors "Data processing", "Research and development" and "Telecommunications" are less significant. Only about a quarter of knowledge-intensive services are technology-oriented in the narrow sense of the term, which explains the need for large numbers of graduates who do not have a background in the natural sciences or engineering. However, the non-technological service sectors also demand high-value technology, as for example in the cases of "Health", "Finances" or "Non-technological consultancy".

Over the past decade, the trend to tertiarisation[125] has continued; the proportion of employees working in business services has risen from 55 percent in 1998 to 61 percent in 2007. In the medium-term, communications services and non-technological consultancy services have the highest employment dynamics; in financial services the employment has been declining since 2002.

Steadily growing proportion of graduates in all sectors of the economy

The continually rising importance of the research- and knowledge-intensive sectors increases the demand for high level education. The dynamic development of the economic structure thus exerts a considerable influence on the requirements placed on the education, science and research systems. In these sectors, innovation is usually a key determinant of the ability to compete, and the innovation pressure is much higher than in other parts of the economy. This resulted in a boost in demand for highly-qualified professionals, in particular academics, who play a key role in innovation competition.

The proportion of highly-qualified professionals employed by companies is increasing steadily. In 1998, 6.9 percent of the workforce were graduates, in 2007 8.6 percent. In 2007, more than 1.9 million highly-qualified professionals were employed in businesses in Germany,[126] of which there were some 700 000 natural scientists and engineers and more than 1.2 million graduates in other disciplines. In each case, about three-quarters of the sub-group were working in knowledge-intensive branches of the economy. Most natural scientists and engineers work in the manufacturing sector, and a majority of graduates from other disciplines work in the services sector (Fig. 34).

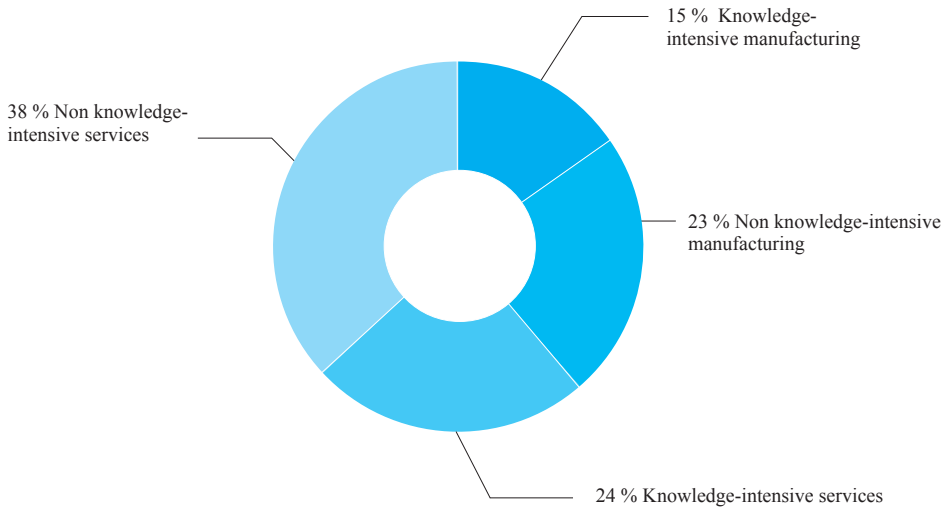
The orientation of the knowledge-intensive services towards non-scientific academic qualifications can even be observed in the communications services, where the proportion of other graduates is five-times higher than that of natural scientists and engineers. The differences in qualification requirements are also reflected in the middle segment of skilled personnel with vocational training qualifications:[127] The corresponding rate for the knowledge-intensive branches is nearly 78 percent, in the non-knowledge-intensive branches it is only 62 percent.

The change in the numbers of graduates can be attributed to three effects:

- The trend effect reflects the part of the change which is due to changes in the economy as a whole, i.e. economic growth or stagnation.
- The structural effect is the result of the shift of the economic structure towards knowledge-intensive sectors.
- The knowledge intensification effect reflects the higher qualification requirements in the sector.

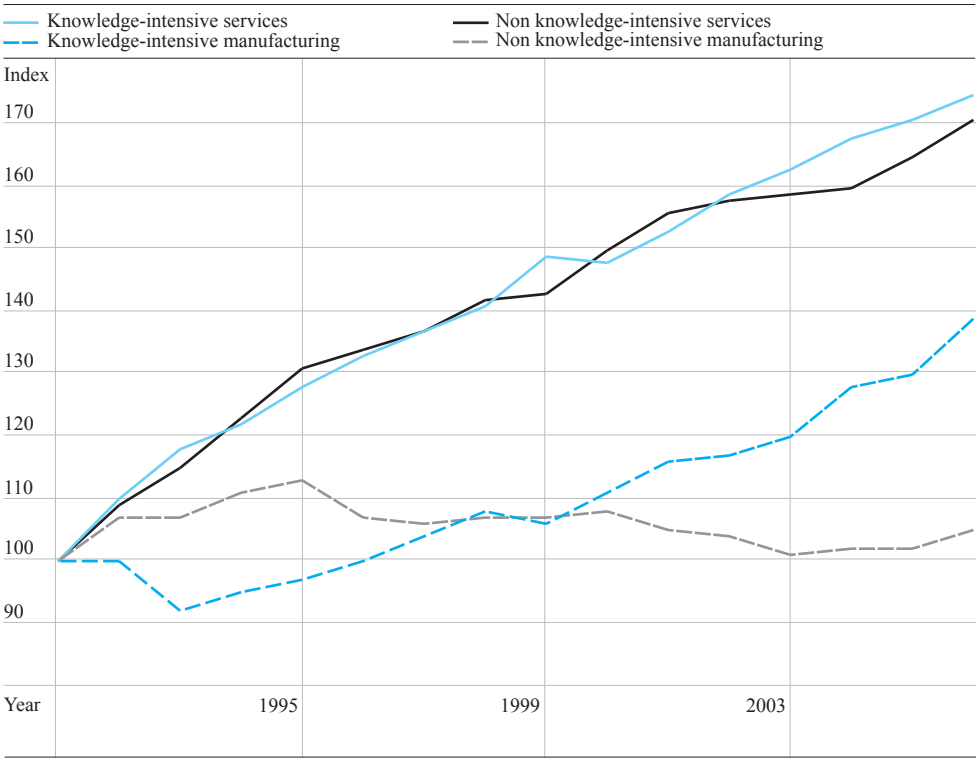
Only in the recent phase from 2005 to 2007 did the overall rise in the employment volume also lead to an increased demand for highly-qualified professionals

Share of employees in various types of businesses in Germany FIG 32



Data 2007. Source: Bundesagentur für Arbeit, Statistik der sozialversicherungspflichtig Beschäftigten.
Calculations and estimates of NIW.

Development of gross value creation in various business sectors in Germany[128] FIG 33



Index: 1998 = 100. Share of knowledge-intensive manufacturing 21 %, Other manufacturing 16 %,
Knowledge-intensive services 37 %, Other services 26 %.
Source: Statistisches Bundesamt, Series 18, 1.4. Calculations by NIW.

(trend effect). The effect of the structural change to knowledge-intensive sectors was a key factor above all from 1998 to 2002, particularly for knowledge-intensive services. Knowledge intensification was the most important factor from 1998 to 2007, especially in the most recent observation period from 2005 to 2007. Since 2002 the non-knowledge-intensive sector has also been generating significant demand for graduates.

Shortage of natural scientists and engineers restricts growth

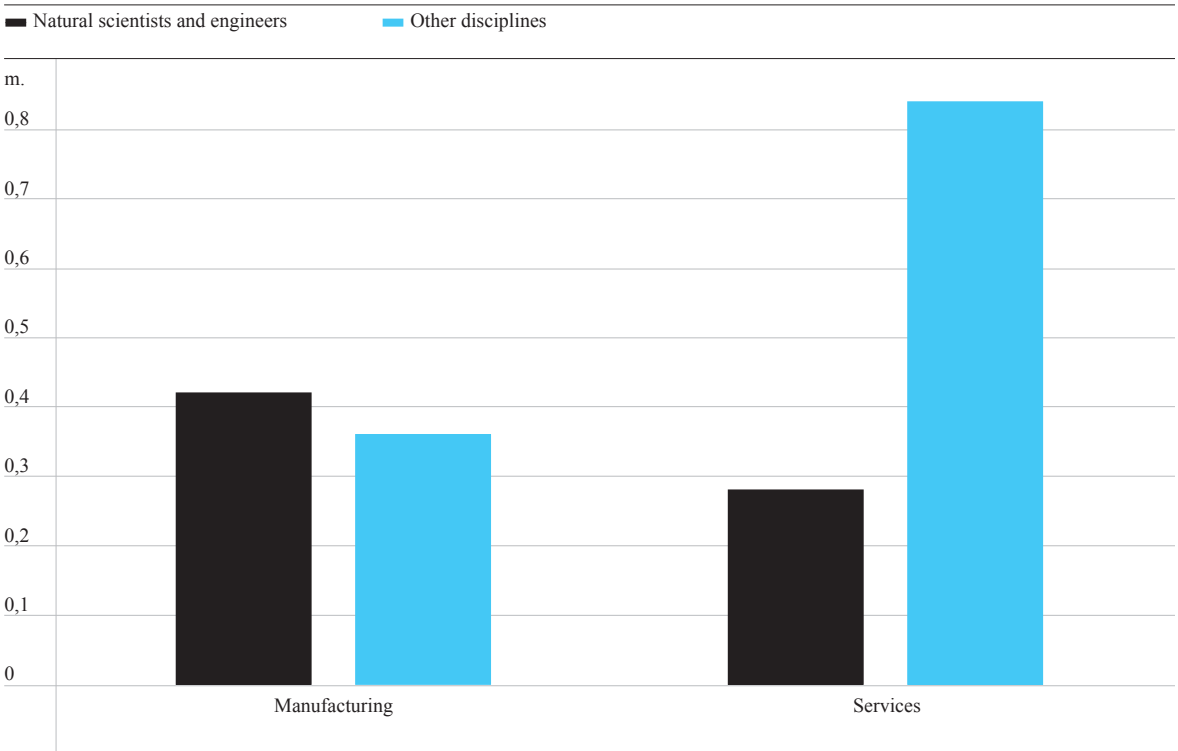
The employment of natural scientists and engineers is influenced by economic fluctuations; it even declined in the period from 2002 to 2005, which affected nearly all economic sectors with the important exception of the automotive sector. In contrast, the overall employment of graduates increased slightly during this economically weak period. The decline in the employment of natural scientists and engineers was probably influenced to some extent by cost considerations on the part of individual businesses. This may have been a rational management attitude, but as a signal for students newly enrolling in these subjects at university it was rather unfortunate. The problematic showed itself in the upswing period 2005 to 2007, during which 152 000 graduates were newly recruited, but of these only 20 800 were natural scientists and engineers, because the employment market did not have enough people with the relevant qualifications. This situation had not changed significantly by 2007, so that the shortage of natural scientists and engineers is already seriously limiting growth and innovation.

A particular problem in Germany is the rising average age of the natural scientists and engineers. The proportion of 25- to 34-year-olds in this group is not only the lowest in the EU-27 (20 percent), but it has also decreased by 2.6 percent from 2001 to 2006. Overall, as a result of innovations and structural changes, Germany can reckon with an additional demand for 40 000 to 50 000 graduates.

Clear trend to a knowledge economy throughout Europe

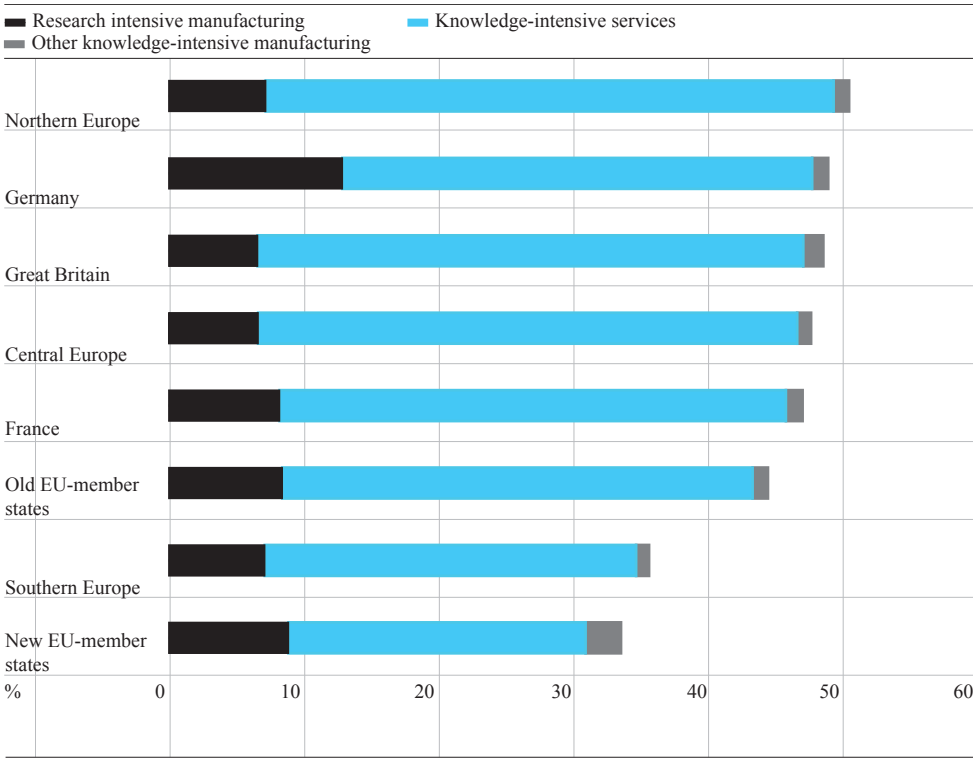
The employment structures in the other established EU Member States (EU-14)[129] are very similar to

FIG 34 **No. of graduates employed in the German business sector**



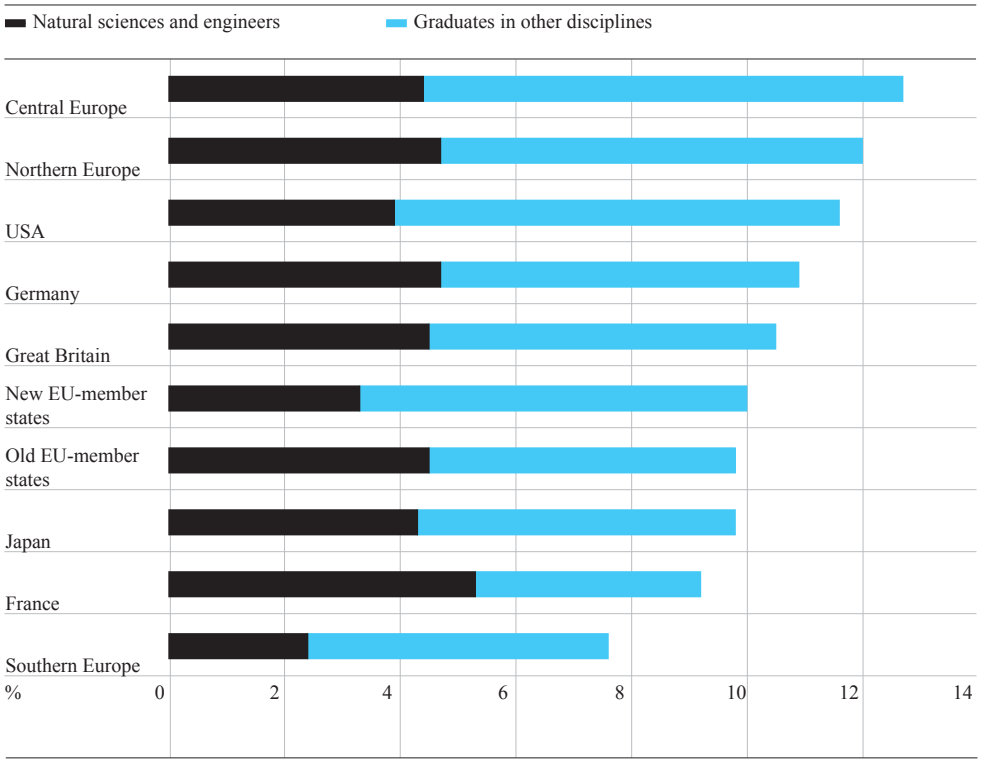
Data: 2007.
Source: Bundesagentur für Arbeit, Statistik der sozialversicherungspflichtig Beschäftigten. Calculations and estimates of NIW.

Share of employees working in research- and knowledge-intensive companies in Europe FIG 35



Northern Europe: DK, IR, SE, FI, IS, NO. Central Europe (without DE): BE, LU, NL, AT, CH. Southern Europe: IT, GR, ES, PT. Source: Eurostat, CLFS. Calculations by NIW.

Share of employees with degrees in businesses in selected countries and regions[130] FIG 36



Data: 2007. Sources: Eurostat, CLFS, USA: Bureau of Labor Statistics, OES. Japan: Statistics Bureau and the Director General for Policy Planning. Population Census of Japan. Calculations and estimates of NIW.

Germany's: 45 percent of all employees in the business sector are working in research- and knowledge-intensive sectors (Fig. 35).

In the Northern Europe region, more than half of the workforce are active in the business economy. This region is thus the most advanced in Europe in the structural transformation to the knowledge economy, closely followed by Germany and Great Britain. The southern European countries are a long way behind with nearly 36 percent employed in the knowledge-intensive sectors. This is only a little ahead of the younger EU Member States (EU-12) with 33.5 percent, but their "catching-up process" is much more dynamic than is the case with Portugal or Greece. In a European comparison, the higher proportion in research-intensive manufacturing sector in Germany is remarkable, while Northern Europe, Great Britain and Core Europe focus on knowledge-intensive services.

Germany is slightly ahead of Great Britain in the employment of graduates and well above the EU-15 average.[131] But it is clearly behind Central and Northern Europe and also the USA (Fig. 36). This reflects the weight of knowledge-intensive services in these countries, which is based to a particularly high level on mainly non-science graduates. Germany employs a particularly high proportion of natural scientists and engineers. The reason for this is the disproportionally high structural weight of the research-intensive manufacturing sectors. Nevertheless, the corresponding rates in Northern Europe and the Core Region and Great Britain are meanwhile similarly high. This means that Germany has lost its "knowledge lead" over most European regions for natural scientists and engineers. From a German point of view there is now only a knowledge advantage over Southern Europe and the new EU Member States, although the knowledge gap to the quickly growing EU-12-Member States has already become much smaller.

When assessing the knowledge-intensive services it must be borne in mind that sub-sectors can have very different significance in different countries. In Germany, "Health" is a particular important sub-sector in terms of the employment rate. In Sweden and Finland "Health" also has a very high rate, whereas in Great Britain and the Netherlands "Company consultancy" and "Finances" are highly represented.

Over the past ten years, knowledge-intensive sectors have been in front in the services sector in the EU-15 countries with growth rates of 3 percent per annum, and also in the manufacturing sector there is an increasing structural change to knowledge- and research-intensive branches. The IC sector has advanced in this period, which is above all due to an enormous expansion of data processing services with an increase of 8 percent per annum.

Considerable demand for graduates throughout Europe

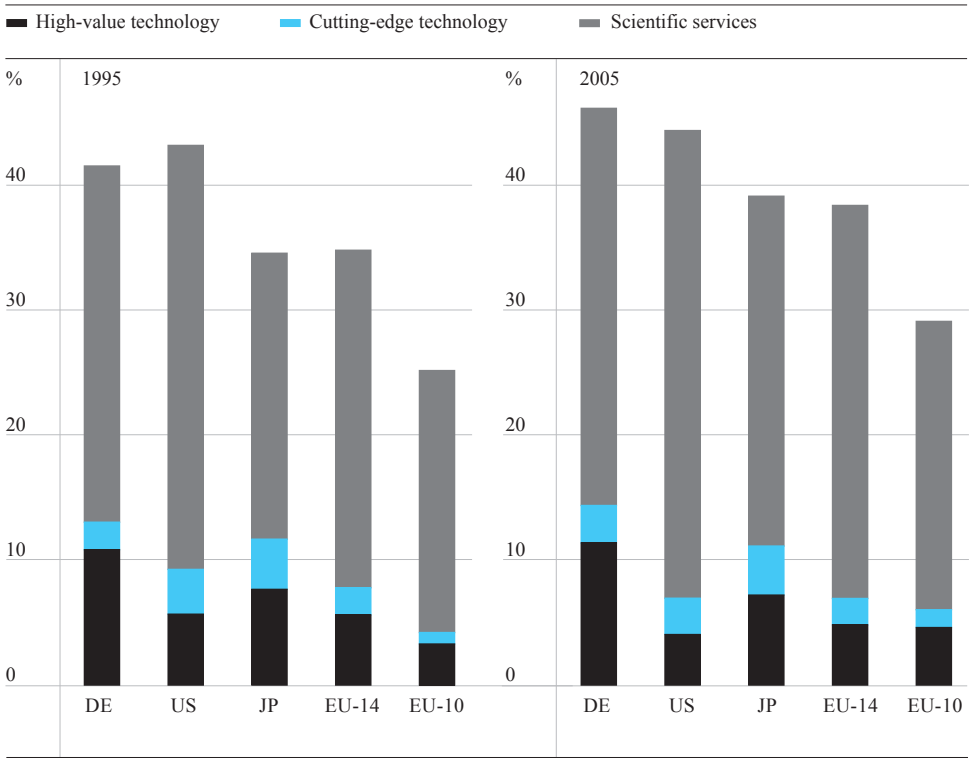
An analysis of the demand for highly-qualified professionals in European regions shows that, as in Germany, the shift to knowledge-intensive sectors and above all the knowledge intensification in the sectors has led to increased demand for graduates. This must be interpreted as a reaction by the companies to the increasing innovation pressure, which is perceived throughout the manufacturing sector to a greater extent than in the services sector and in the rest of the economy.

This development leads in Europe as a whole to a continually increasing demand for highly-qualified professionals. The hope of many countries in Northern and Central Europe that they will be able to meet at least part of their growing need for qualified personnel by attracting people from Eastern Europe, is hardly likely to come to fruition, because in the Eastern European accession countries the levels of graduate employment are rising at about twice the rate of the the old EU member states. In fact, there is therefore more likely to be a return of highly-qualified professionals to Eastern Europe.

Germany still successful with high-value technology

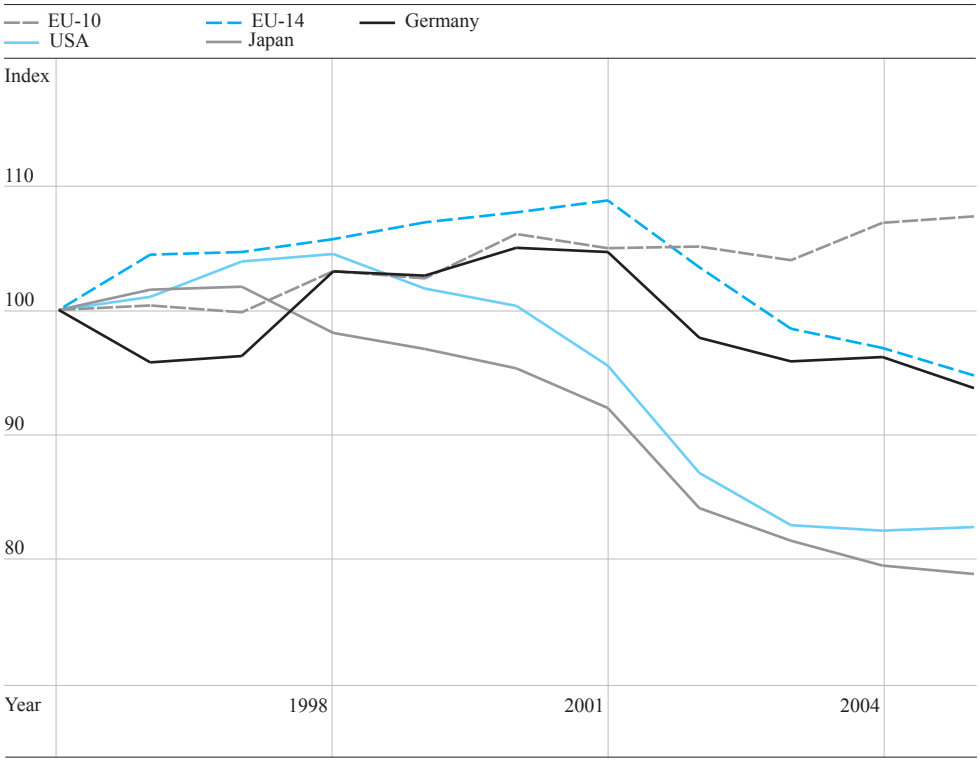
A comparison of Germany with the USA, Japan, and the old and new EU member states for the period from 1995 to 2005, shows that labour employment and value-creation in the manufacturing sector has sunk in nearly all regions (Fig. 37). There was only an increase in the new EU member states in cutting-edge technology. But for commercial knowledge-intensive services they increased everywhere. The greatest growth was in the old EU member states, and

Proportion of value created by R&D-intensive manufacturing sector and knowledge-intensive services in selected countries and regions FIG 37



EU-10: new member states without Romania and Bulgaria, EU-14: old EU member states without Germany.
Source: EUKLEMS Database 3.2008. Calculations and estimates of DIW.

Development of employment in cutting-edge technology in selected countries and regions[132] FIG 38



Index: 1995 = 100. EU-10: new member states without Romania and Bulgaria. EU-14: old EU member states without Germany. Sources: EUKLEMS-Database 3.2008. Calculations and estimates by DIW.

Germany was also involved in this positive trend. In the course of the past decade, Germany has always been more intensely oriented towards the research- and knowledge-intensive sectors of the economy. The share of this sector in Germany is meanwhile well above the average of the old EU member states and ahead of the USA. This is due above all to the traditionally very high share of high-value technology. Overall, the demand for high-value technol-ogy goods was more robust than for cutting-edge technology goods. Here, the USA and Japan were particularly heavily hit by the IC crisis, which led to a significant drop in the labour employment in the cutting-edge technology sector (Fig. 38).For knowledge-intensive services, measured in terms of overall employment of labour and the value-creation rate, Germany has a mid-table position between the USA and Japan (Fig. 37). The strong position of the USA is due mainly to the considerable weight of the "Finances" sector. There will certainly be significant alterations here in view of the financial crisis. The weak position of Japan can be explained mainly by the low presence of Finances and Health. Despite the developments outlined above, the intensive deployment of IC technologies is indispensable for maintain-ing a competitive position in the research-intensive manufacturing sectors and in the knowledge-intensive services sector. A closer analysis of the growth contributions shows that America's good IC infrastructure, above all for the knowledge-intensive services, made an important contribution to productivity. In comparison, the productivity development in the R&D-intensive manufacturing sectors and the knowledge-intensive services in the past ten years in Germany was weaker. Nevertheless, German companies were extremely successful in international markets. Obviously they could obtain relatively high prices in their fields of specialist production, whereas the USA and Japan suffered under the falling prices of IC-products (Fig. 38).

After a more precise statistical analysis, it is not possible to explain the change in the competitive positions in the various sub-sectors of cutting-edge technology and high-value technology in terms of the differences in productivity developments. Clearly, short-term economic aspects do not play a central role in competition. A more important factor seems to be the specialisation profile, i.e. the experience accumulated over a period of time in specific areas of production and services.

Strong growth of foreign trade worldwide

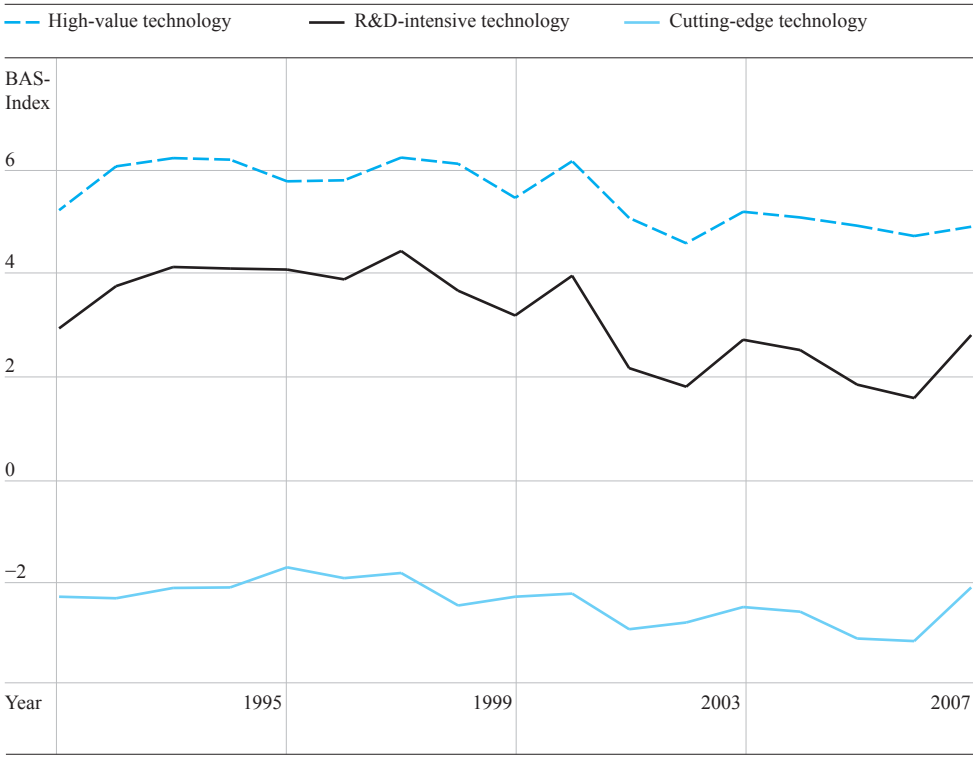
World trade with technology-intensive goods has increased considerably in recent years. Since 2002, the last low-point in the global economy, this trade has increased at an average annual rate of 14 percent, although the exports of non-R&D-intensive products grew at 18 percent p.a. In contrast, cutting-edge technology goods have become relatively less important, with a growth rate of 12 percent. The main reason is the falling prices of goods in the IT and electronics sectors, which resulted in declining shares in trade values. R&D-intensive products accounted for 55 percent of all worldwide exports in 2007.

Germany's manufacturing sector has long been focussed on foreign trade and has participated in the general growth in world trade. Between 2000 and 2007 the goods export rate of 29 percent rose to more than 40 percent. The export sector is becoming increasingly dominant and it exerts a fairly decisive influence on the structures of the research-intensive manufacturing sector. Germany has a leading position in terms of its export rate among the large countries. The export rate of France in 2007 was 21 percent, and of Great Britain was 16 percent. Only smaller countries are more strongly export-oriented, such as Austria (44 percent) and above all the Netherlands and Belgium (71 percent and 94 percent, respectively).

Foreign trade position of Germany improving further

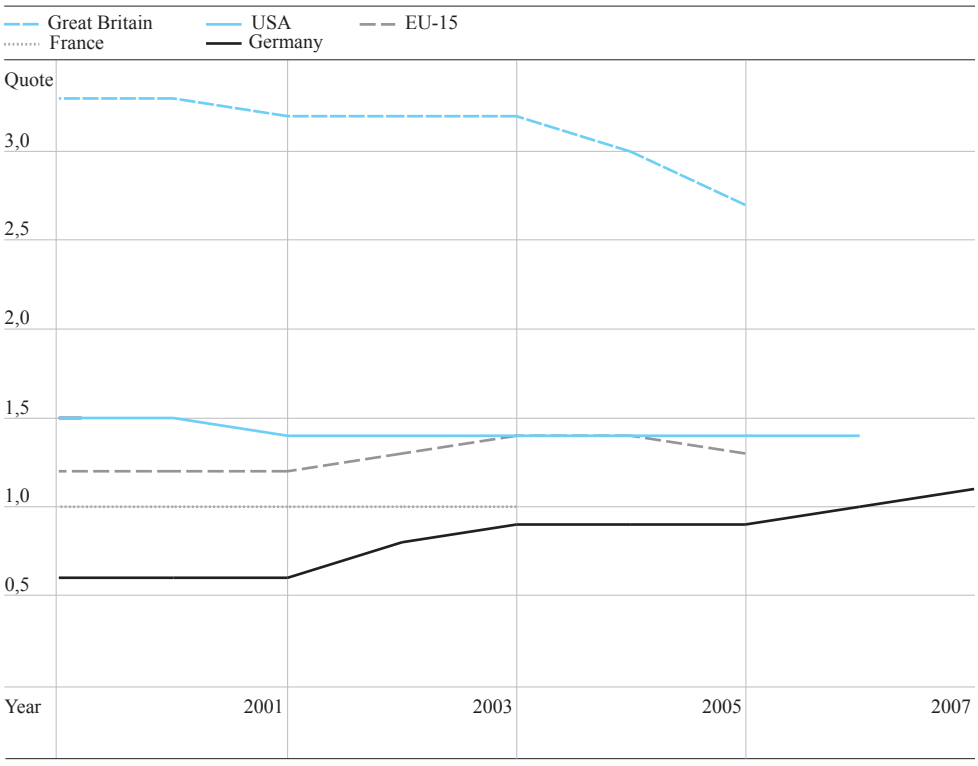
The competitiveness of Germany in foreign-trade with technology-intensive goods has improved further in 2007. This is due in part to a somewhat stronger position with high-value technology goods, and in part also to an improved position with cutting-edge technology goods, although the orientation to cutting-edge technology is still much below average by international standards. The most important factor for the situation in the cutting-edge technology is a marked increase in foreign trade with aircraft and spacecraft. This is the largest single item, accounting for 21 percent of cutting-edge technology exports. However, this improvement should not be overrated because in the past there have frequently been considerable fluctuations and also much of the foreign trade is actually related to cross-bookings made internally by Airbus.

The contribution of R&D-intensive goods to the foreign trade balance of Germany FIG 39



Goods of classes SITC 5 bis 9 without 68.[133] 0 = average, above +1 = considerably above average.
Source: UN-Data. Calculations by RWI.

Cover ratio of foreign trade with knowledge-intensive services from selected countries and the old EU member states FIG 40



Cover ratio = Exports/Imports. Source: OECD Stat. Dataset: Trade in Services by Category. Data of German Bundesbank and IMF. Calculations and estimates by NIW, RWI and Fraunhofer ISI.

The foreign trade position of a country is frequently presented using a specialisation index, the RCA index[134] (see Box 24). Here this includes the relations of exports to imports, so that the developments of both components have to be taken into consideration.

Between 1997 and 2002, the relative export share of Germany generally improved. But between 2002 and 2007 the constellation was exactly the other way round: the relative export share of R&D-intensive goods worsened, which was hardly surprising in view of the arrival of new competitors from the emerging markets. At the same time, the increasing competitiveness of German producers led to a reduction in the import pressure, and this was particularly evident in cutting-edge technology.

The RCA index only reflects the trading situation of a group of goods in comparison with the average for all goods. This led for example in 2007 to an above-average index for all R&D-intensive products (+10), an even higher value for the high-value technology (+25) and a very negative value for the cutting-edge technology (−32).[135] In contrast, the contribution to the balance of trade not only considers the specialisation but also the volume of the trade with the goods in question and thus better reflects the real situation. In 2007, this index was 2.8 overall; this included cutting-edge technology with −2.1 and high-value technology with 4.9. The negative specialisation of the cutting-edge technology is not as pronounced when expressed in this way, because the volume traded is low in comparison with high-value technology (Fig. 39). In the high-value technology, "Motor vehicles" with 3.7 accounts for some 75 percent, which documents the dominance of this sub-sector. The anticipated decline in the automotive industry will therefore have a marked impact on the foreign trade position of Germany with high-value technology.

Services currently account for about a fifth of world trade, so that these have gained a considerable importance. In 2007, Germany had 6.8 percent of world trade in services and was only in third place, some way behind the USA (15.5 percent) and Great Britain (11.7 percent). German companies are less well positioned here than with goods exports.[136] For knowledge-intensive services, they have considerably improved their cover ratio since the mid-1990s and meanwhile have a positive value, so that a good international position has been reached. However the EU-15, the USA and in particular Great Britain have a higher ratio, so that – as with domestic value-creation – Germany has a weaker position for foreign trade with services in an international comparison.

In Germany, consultancy services are the largest services exports item in the knowledge-intensive sector (42 percent in 2006), followed by about a quarter for communications and media, 20 percent for finances and 14 percent for research (Fig. 40). In the USA, the main positive contributions are from the sectors communications and media; research services had been strong but were declining since 2001; the contribution of finances was only just positive in 2006. The above-average cover ratio – or the high foreign trade balance – of Great Britain is due to good ratios in all sub-sectors, in particular finances.

This review has drawn on important results from more extensive studies:

- Gehrke und Legler (2009) deal with production, foreign revenue, employment and value-creation of research-intensive manufacturing companies in Germany. Value-creation and employment in knowledge-intensive services are investigated. An additional topic is knowledge-intensification and qualification requirements, in particular also in a European comparison.
- Belitz et al. (2009) analyse the link between labour productivity and specialisation in R&D-intensive technology. They also examine the structural changes in labour deployment and value-creation in a comparison of Germany and the EU with the USA and Japan.
- On this basis, they analyse growth contributions in the research- and knowledge-intensive sector and other sectors.
- Döhrn and Stiebale (2009) consider changes in the foreign trade structure of Germany in recent years and investigate the interconnection of technology and knowledge-intensive sectors through direct investments.
- Gehrke et al. (2009) address the quantitative surveying of knowledge-intensive services and also investigate foreign trade in services.