Commission of Experts for Research and Innovation (EFI), Berlin (ed.)

Research Report

Research, innovation and technological performance in Germany - EFI Report 2008

Research, innovation and technological performance in Germany: Report, No. 2008e

RESEARCH, INNOVATION
AND TECHNOLOGICAL
PERFORMANCE IN GERMANY

EXPERTENKOMMISSION
FORSCHUNG
UND INNOVATION
EFI

REPORT 2008

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Published by
Commission of Experts for Research and Innovation (EFI), Berlin.

Citation as
Commission of Experts for Research and Innovation (EFI) (Ed.): Research, innovation and technological performance in Germany – EFI Report 2008, 2008 Berlin.

Design
Design: Kognito Visuelle Gestaltung, Berlin
Layout: Fraunhofer ISI, Karlsruhe, Jeanette Braun
Production: Druckhaus Berlin-Mitte GmbH, Berlin

Translation
Translation: Richard Holmes, Berlin

ISBN: 978-3-00-025547-2

Berlin, February 2008

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SUMMARY

Research and innovation are extremely important for Germany. New insights are generated by research, and new ways of creating value are opened up by technical, organisational, and other innovations. Production, value-creation and employment tend to increase much more in companies which are highly innovative. The public sector can become more efficient and customer-oriented through the implementation of innovations, which also have a positive influence on people's welfare and their quality of life.

Against this background, Germany's politicians have increasingly been considering how best to promote research and innovation, and where the country ranks in the international innovation contest. The Federal Government of Germany therefore decided in 2006 to establish an independent Commission of Experts on Research and Innovation (EFI), with the remit to analyse the structures, trends, performance, and prospects of the German research and innovation system, and to formulate policy recommendations for its further development. This report is the result of our work to achieve this goal.

The current situation

Over a broad range of research and innovation, Germany can draw a positive balance. Its trade surplus is generated mostly through products and services that are highly innovative and technologically sophisticated. Germany is a leading nation worldwide when it comes to patenting inventions and publishing scientific findings. In recent years, important new policies have been adopted in order to prepare the country for growing competition and the challenge of a knowledge economy. The recent increases in overall expenditure on research and development (R&D) are a first sign that the measures are having an effect. However, Germany is still confronted with growing challenges. Government, companies, and research and education institutions cannot be satisfied with what has been achieved in the past.

Challenges for Germany as a location for innovation

The Commission of Experts on Research and Innovation has identified the following challenges for Germany as an innovation location:

– Germany has achieved considerable progress in recent years through its Excellence Initiative, the Hightech Strategy, and other measures. But international competitors are also growing stronger. Other industrialised countries are increasing their innovation activities, and emerging nations are becoming serious economic competitors. Germany has to defend and develop its position. Government and companies must redouble their research and innovation efforts.
– Despite recent reforms, the German company taxation system continues to impede innovation in many areas. It must be restructured so as to provide more support for research and innovation.
– The traditional German educational system, which was successful for a long period, has fallen behind in international comparisons. Shortages of skilled labour are already a problem in many sectors, and will represent a long-term constraint for the innovation system unless sustainable countermeasures are adopted energetically.
– The coordination of research and innovation policies is becoming an increasingly demanding task. The Hightech Strategy, which has proved an important step towards making the national R&I policy more effective, must be further developed and optimised. Inno-

vative services should be given broader consideration, and the Sustainable Development Strategy has to be more focused.

– For the most part, German innovations are oriented towards established industries. The growth potentials of markets of the future are not being tapped to a sufficient extent, although the research in Germany would provide a good basis for this. Research and innovation in cutting-edge technology has to be more strongly promoted. Obstructions must be removed which impede the founding of growth oriented new enterprises and hinder the provision of start-up financing.

Steps towards innovation-friendly financing and fiscal policy

An essential pre-requisite for innovations is adequate funding. But banks are reluctant to make the necessary funds available to inexperienced innovative enterprises, which are therefore often forced to rely on their own capital. The low equity ratio is also impeding innovation in the German mittelstand (medium-sized companies). These financing bottlenecks could be relaxed at least in part with the help of external investments. However, in comparison with the size of the German economy, the equity investment market is clearly underdeveloped.

Because equity is so important for financing innovations, the fiscal provisions for both the companies and external investors are crucial. However, equity capital is treated less favourably than loans under existing German tax legislation. Whereas interest paid on loans taken out by a company can be booked as an operating expense, financing by equity capital meets with double taxation, namely on the part of the company and the external investor. The Commission of Experts criticizes this.

Similar criticism applies to the anomaly in the treatment of profits and losses. While the state always benefits from profits through the taxation system, companies can only partially recognise the losses which are regularly incurred in the course of innovation projects. The Commission of Experts recommends the elimination of this fiscal impediment to research and innovation.

In an international comparison, the framework conditions in Germany are poor not only for the companies, but also for external investors. This is primarily due to the legal uncertainty about whether equity investment companies manage assets or are commercially active. The classification under one category or the other has a considerable effect on the tax situation, and the overall result is a clear reduction in the level of foreign equity capital invested in Germany.

The general conditions for venture capital should be improved by the legislation on venture capital companies coming into force in 2008. Although this law is a step in the right direction, the limited scope does not provide much hope for sweeping improvements. The Commission of Experts suggests dropping the limitations in the draft legislation in order to achieve an effective and internationally competitive promotion of venture capital funding.

In order to provide companies in Germany with R&D funding that is uncomplicated and which provides a sound basis for long-term planning, the Commission of Experts advises the development of a tax provision like those that have been successfully implemented in many OECD and EU member states. Because of the downward trend in the contributions to innovation by small and medium-sized enterprises in Germany, it is recommended that SMEs should be given preferential treatment. This can also be justified for other reasons. Financing restrictions and the above-mentioned fiscal anomalies concerning equity and loans are a particular problem for SMEs and new enterprises, whereas larger companies are less affected. The broad promotion of R&D through the taxation system could represent a sensible addition to the targeted R&D project promotion that should continue to be provided in specific situations. In this way the two measures would complement one another. In addition, tax rebates for R&D could provide important impulses for reaching the so called Lisbon goal of spending three per cent of GDP on research and development.

Shortage of skilled labour burdens the innovation system – Urgent need to expand the education system

Germany's educational system has fallen far behind the leaders in an international comparison, with grave consequences for innovative competitiveness. The government and the business sector have recognised the challenges. Measures for improving the educational system have to start in the early phases of education.

Despite all its efforts, in an international comparison Germany has a small proportion of highly qualified young people, and a particularly large proportion who are poorly qualified. The latter are mainly children from disadvantaged social strata and children with a migration background. The percentage of young people who are poorly qualified must be reduced dramatically, because this group will only be able to participate in innovation to a limited extent. The proportion of young people going on to higher education has to be increased considerably, especially in the natural sciences and engineering.

In recent years, German companies have been showing a decreasing willingness to invest in continuous education, even though Germany already has a very low baseline level by international comparison. Many employers and employees do not see continuous education as an investment in the future. The Commission of Experts regards an increase in the rate of continuous education as being crucial for maintaining Germany as a location for innovation.

Due to demographic developments, the numbers of people with good training in Germany will soon decline in absolute terms. This is in contrast to the growing demand for highly qualified personnel. Skilled personnel will be in increasingly short supply. There are various ways to increase the numbers of well-trained personnel: to have a higher proportion of women in employment, to improve the educational opportunities for the socially disadvantaged, to decrease the proportion of students who drop out of university, and to selectively admit skilled personnel from foreign countries. Such measures cannot be adopted in a piecemeal fashion. They have to be implemented in parallel, and in combination with continuous education.

Increasing innovative potential will require an overall upgrading of the educational system. The Commission regards a package of measures as being indispensable, beginning in early. These steps require an appreciable increase in budget expenditures on education. However, the failure to take action would prove much more costly for the German economy.

The Hightech Strategy mobilises forces – Exploiting the potential for improvements

The Hightech Strategy of the Federal Government is an important step in the further development of research and innovation activities. The Commission of Experts expressly welcomes the fact that the strategy brings together the efforts of various departments and makes these more coherent. The mobilising effect of the Hightech Strategy is unmistakeable. The strategy aims to proceed selectively and to concentrate the federal support on selected technologies and cross-sectional measures, which raises the obvious question of the criteria to be used to select the fields of technology which receive support. The Commission of Experts recommends formulating these criteria systematically, presenting them more transparently, and applying instruments of technology foresight in an interdisciplinary fashion.

The Hightech Strategy is well-known among German enterprises, and they show a gratifying preparedness to increase their R&D budgets. The precision of the strategy can be improved even more in the course of further development if innovative services are incorporated to a much greater extent, because these play a key role for the economy and the generation of employment.

Environment, climate and sustainability form a truly global complex of problems that will have to be overcome. While the German government has already focused on these issues, the profile still needs to be specified much more clearly. The Commission of Experts proposes placing the strategic emphasis on 'sustainable business'. In particular they are understood as a bundle, sustainable energy management, environmental technologies, sustainable production, resource efficiency, and climate research offer a suitable starting point for the promotion of sustainable innovation.

Germany has excellent opportunities in the field of sustainable business to develop appropriate technologies and services which can be sold on the global market. This will not only facilitate sustainable business in industrialised and industrializing countries, but will also help to establish new lead markets in Germany.

Incremental innovations and radical innovations

Germany is successful with innovation in the field of value-intensive technology, but when it comes to R&D intensive, cutting-edge technology it does not rank so highly. It benefits only slightly from the above-average global growth in cutting-edge technology and in knowledge-intensive services.

In order to enjoy a greater share of the growth in these sectors, Germany must draw on new potential for value creation, particularly on the basis of findings from basic research. Constraints on such innovations must be eliminated in order to make it easier to establish future industries in Germany while at the same time also increasing the innovative advantages in established industries.

The driving force for radically new forms of value creation is provided by new enterprises. However, in Germany, there are no signs of a drive to start up new companies in cutting-edge technologies and knowledge-intensive services. Low numbers of start-ups could mean that new technologies will not be established quickly enough. Better use should be made of this opportunity to generate sustainable employment effects in competition with other locations.

This weakness in setting up new enterprises is attributable to various causes, and it has been influenced by the fact that the entrepreneurial culture in Germany has been underdeveloped for a long time. The financing and tax situations as well as the many bureaucratic obstacles in the way of setting up in business, while not the sole factors, also contribute considerably to an unfavourable environment for new businesses. The Commission of Experts recommends that the Federal Government continues to work towards improving the framework conditions for setting up new enterprises in the cutting-edge technologies in Germany.

A

A OUR REMIT

Research and innovation are essential for highly developed countries such as Germany which are poor in resources. Innovative goods and services keep the economy going and generate employment and high incomes. The welfare of the country and the future and quality of life of its people are dependent on it. But how can policy-makers establish a sound foundation for research and innovation? In which fields should politicians be active, where should they hold back? The German Federal Government regularly turns to experts for advice, and on 23 August 2006 they decided to establish the Commission of Experts for Research and Innovation (EFI). This body held its first meeting on 28 February 2007.

The Expert Commission for Research and Innovation has been given the following remit:

1. The Expert Commission for Research and Innovation draws together the interdisciplinary discourse relating to innovation research in the fields of economics and social sciences, educational economics, engineering and natural sciences, and technology forecasting.
2. The Expert Commission for Research and Innovation should provide scientific policy advice in the following fields:
   – Presentation and analysis of the structures, trends, performance potential and prospects of the German research and innovation system over time in an international comparison,
   – The presentation of reports on key aspects of the German system of research and innovation,
   – Development of possible options for future actions and recommendations for the further development of the German research and innovation system.

This document is the first such report presented by the Expert Commission. We intend to present future reports annually on the 1st March. Such a report must endeavour to be up-to-date, but in most cases the data situation will not allow statements to be made about the year immediately preceding the report. In order to be able to judge structural changes in research and innovation, developments must be considered over a longer period.

In previous years, German research and innovation policy-makers have been able to draw on a detailed and sophisticated reporting system on technological performance. The Expert Commission for Research and Innovation is building on this foundation. We are systematically developing the indicator systems for the analysis and description of innovation processes, and we report on this basis about the developments in the German innovation system. In addition, key topics are presented which are of vital importance for the economy and society. On the basis of these analyses, options will be discussed for future decisions in research and innovation policy.

The central results of the work of the Commission will be published in the annual reports. These will focus on the development of an overall assessment and the formulation of priority recommendations for research and innovation policy. Detailed information and data can be obtained from the studies of the German innovation system, for which the Expert Commission now acts as editor and which are available on the EFI Website (www.e-fi.de).

More than a century ago, the German-speaking countries were setting standards for education, scientific research and industrial product development. The Expert Commission for

Research and Innovation sees it as a challenge to contribute towards helping Germany to take up this role once again and develop it further at the start of the 21st century.

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CORE TASKS OF THE NATIONAL RESEARCH AND INNOVATION POLICY

B

B CORE TASKS OF THE NATIONAL RESEARCH AND INNOVATION POLICY

Objectives of the research and innovation policy

National research and innovation policies are aimed at ensuring that research and innovation processes are of long-term public benefit and that advances can be achieved which are of importance for society. The focus of R&I policies is on the promotion of research and innovation and on the promulgation of research results and new technologies. R&I policies pursue a series of core tasks.

Shaping the national research and innovation system

Research and innovation activities take place within a complex network of state and private institutions. R&I policies have to take into account specific national features. The core tasks include the long-term development of the national R&I system, and this involves various sub-tasks such as:

- The institutional and organisational shaping of public research and its promotion,
- The formation of interfaces between the private and public institutions and between the actors in the innovation system, including the formation of public-private partnerships,
- Specification of principles for the selection of instruments for the promotion of research and innovation, favouring a system of intermediaries, e.g. the German Research Foundation (DFG), and the inclusion of project organisers in the promotion set up,
- The examination of the effectiveness and efficiency of utilisation of funds in the R&I system, with the regular evaluation of promotional measures,
- The coordination of R&I policies with policies in the fields of education, economics, finances and other areas,
- The transfer of specific R&I topics to individual departments and the dynamic separation of department responsibilities in Germany,
- The coordination of national R&I policies with other political levels, in particular with the federal *laender* and the European Union.

Reinforcing private stimuli for research and innovation

The majority of research and innovation in Germany is carried out by private entities (mostly business companies).[1] But because the associated knowledge often has the character of a public good, market forces alone cannot create suitable incentives for research and

BOX 01

Innovation and competition

The Expert Commission uses innovation in a broad sense to refer to all novel technological, organisational, social, and other developments which have been or are being implemented. It has to be more than just a 'good idea'. In a market economy, innovation involves the development and commercialisation of new products and services or the internal deployment of such innovations (process innovation). In public institutions, innovations involve the introduction of new methods, processes, and procedures.

Innovations can create long-term competitive advantages for the innovative companies. Successful innovators may be able to benefit for a long period from past successes and repeatedly achieve an advantage over competitors. In rare cases, innovations can lead regionally or nationally to the formation of completely new industries. New industries or new products may displace existing industries or existing products and in this way lead to a rejuvenation of the economy. The effect of these dynamic processes is sometimes referred to as 'creative destruction'.

BOX 02

Research and development (R&D)

The Frascati Manual of the OECD defines research and experimental development (R&D) as creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. The Frascati Manual provides recommendations for the statistical registration of the R&D expenditures. R&D is only one component of the innovation processes. Innovation also includes above all the steps of marketing and commercialisation which are not included under R&D.

In order to make quantitative assessments of R&D activities, R&D intensities are calculated. When comparing companies, R&D expenditures are usually related to the turnover. For country comparisons, the entire national R&D expenditure of state and businesses is related to the gross domestic product. In 2006, Germany had an R&D intensity of 2.53 per cent. Six OECD member countries had higher R&D intensities (in some cases much higher): Sweden (3.82 per cent), Finland (3.45 per cent), Japan (3.33 per cent), Korea (2.98 per cent), Switzerland (2.90 per cent), and the USA (2.62 per cent).[2]

innovation. R&I policies can boost inadequate incentives by means of protected property rights (patents, utility model registration, copyrights, etc.) and thus partially correct market insufficiencies.

Innovation activities of private actors can also be promoted to their full extent or by selective financial support. An indirect, broadly-based system of support can be provided by state subsidies for R&D or by the creation of tax advantages which are linked to research activities. Such measures are not associated with specifically directed effects of taxation. However, by targeting resource allocations to individual institutions and actors or by linking these to individual activities in specific fields of technology, R&I policy-makers can intervene directly in the innovation system and steer developments. Balancing the advantages and disadvantages of these instruments and making the most appropriate choices are a crucially important aspect of R&I policies.

Solving general social problems

The R&I policy gives a direction for innovation activities when these relate to overriding or general applications (e.g. in the field of nuclear fusion or space research). We also include aspects of sustainability (including the climate problem) as a general problem of society. Major social challenges can be tackled with what are often termed mission-oriented policies. Research and innovation in such cases are not only policy targets in their own right, but can be the means to an end, that is as a way of achieving clearly defined consequences (e.g. the reduction of CO_2 emissions).

Opening up prospects for the future

Unlike almost any other area of policy-making, R&I policies have the task of opening up options for adding value and increasing knowledge. R&I policy-makers have to analyse new research findings and new social needs, and from these derive new priorities for promotional programmes. Market forces are not usually very well developed in the early phases of the development of new technologies, so that there is more scope for government action than in later phases. For example, in order to exploit the potential of nanotechnology there is a need for forward-looking R&I policies which ensure an adequate stimulus for the new technology long before this is mature enough for commercial utilisation. The R&I policies must also take into account that dominant players in business, science and public administration will not necessarily have much interest in supporting socially-beneficial paths to innovation. Innovations can indeed threaten established positions of power, influence and profit – in the sense of 'creative destruction'. Therefore R&I policies must not be oriented solely in terms of the interests of the big groups of current actors – because the aim in the final analysis is to increase the benefits of research and innovation also for future generations. The unprejudiced consideration of future possibilities is imperative for effective R&I policies.

Research and innovation policy as risk management

Accessing new innovation potential brings with it financial and other risks. The R&I policies must also reflect the importance of the social management of innovation risks. In some cases risks must be limited in order to protect general objectives such as public health and safety. But sensible R&I policies should not aim to avoid all risks at all costs. Anybody wishing to benefit from future innovations must also be prepared to bear the risks during their development, because private interests, encrusted institutional structures and cultural preconceptions can very well lead to highly exaggerated risk avoidance.

Participation in innovation processes

Various options exist concerning the implementation of innovations in an economic system. The ways technologies are utilised is determined to a large extent by economic and social factors. Important decisions concerning the promotion of technologies and innovations are legitimised by parliamentary budget decisions, because the tax money which is allocated in this way will no longer be available for other purposes. R&I policy formulators should encourage public participation in shaping the content of innovation processes, because these can have far-reaching effects on the future of society. For example, instruments of evaluation and technology forecasting can target both scientific elites and the general public.

Establishing stable conditions for the generation and use of knowledge

The discussions about the use of nuclear energy and more recently about the restrictions on the use of stem cells for scientific purposes have shown that decisions about R&I policies can lead to deep divisions in society. R&I policies must attempt to initiate social discourse on controversial ethical questions. In this way it can help to establish stable conditions for the creation and use of knowledge. In order to secure such framework conditions it is equally important that national R&I policies are coordinated with strategies within the European Union and at the regional level.

THE CURRENT SITUATION AND DEVELOPMENTS

C

C THE CURRENT SITUATION AND DEVELOPMENTS

C 1 THE CURRENT SITUATION

In comparison with other OECD member countries, Germany can look back on impressive successes. This is considered further in Section D and also in the separate studies of the German innovation system issued by the Expert Commission for Research and Innovation. Positive factors include:

- The willingness of German companies to pursue innovation,
- The extensive patenting of German discoveries not only in Germany and Europe, but also in the triad (Europe, Japan, USA),
- The considerable exports of technological products from German suppliers.

German companies are very active in innovation. Various studies on the basis of the Community Innovation Surveys have shown that the proportion of innovative companies in Germany is higher than in all other EU member states. In 2004 almost 65 per cent of German industrial companies carried out innovation activities. The comparison shows that in almost all sectors Germany is one of the three leading countries in the EU in terms of innovation tendencies.[3]

Relative to the numbers of people in gainful employment, Germany ranks second internationally behind Switzerland for patent applications. Another positive factor is the patent position of Germany in special fields such as nanotechnology, fuel cells, and wind energy. However, all these fields are still relatively small. In the major field of information and communications technology, Germany is below average. The German patent position is unequivocally positive regarding environmental technologies.[4] Of course, patents cannot be equated with successful innovations. Patented ideas have to be utilised commercially by companies, otherwise they cannot generate any macroeconomic benefits.

Germany continues to return excellent export performance. Germany exported R&D-intensive products (Box 4) to the value of 428.3 billion euros in 2005, making it the leading technology exporter ahead of the USA and Japan. Allowing for technology imports of 264.0 billion euros, Germany was the second largest net exporter of R&D-intensive products behind Japan. Germany's per capita trade surplus for R&D-intensive products is also larger than many smaller economies such as Finland, Switzerland, the Netherlands or Sweden. However, this means that Germany is also highly dependent on its successful export activities with R&D-intensive products.

Structural changes

The studies on the German innovation system published by the Expert Commission indicate important structural changes in recent years. There has been a clear shift in value added towards R&D-intensive industry and knowledge-intensive services. These sectors contribute

BOX 03

Schumpeter goods

Innovations often require prior inputs from research and development in order to extend existing knowledge. But sometimes innovations are also possible on the basis of the current stock of knowledge, i. e. without research and development. 'Schumpeter goods' can be R&D-intensive goods (physical products) or knowledge-intensive services (services products).[5] The term 'high-technology products' is equivalent.

BOX 04

Definitions

The Expert Commission uses the following concepts:

'Schumpeter goods' are R&D-intensive goods and knowledge-intensive services.

R&D-intensive goods are goods for which the production process involves an average expenditure annually of more than 2.5 per cent of the sales revenue on R&D.

A distinction is made between: High-level technology goods: expenditure of 2.5 - 7 per cent of the sales revenue on R&D. Examples include pharmaceutical products, motors, filters, machine tools, medical technology, motor vehicles and rail vehicles.

Cutting-edge technology goods: expenditure of more than 7 per cent of the sales revenue on R&D. Examples are active pharmaceutical substances, IT devices, aircraft and space vehicles.

Knowledge-intensive services involve a high proportion of university graduates (above approximately 11 per cent) and a significant proportion of natural scientists and engineers (more than approximately 4.5 per cent).[6] These include telecommunications services, software services, insurance, architecture and engineering services, legal, fiscal, and management consultancy, veterinary and health matters, communications, libraries, archives, museums.

considerably more to the growth of production, exports and employment than other sectors of the economy. Policy-makers are therefore right to emphasise the special role of research and innovation.

The knowledge-intensive services are growing most and make the largest contribution to job creation. This is part of the on-going structural change towards a services society. But this does not mean that in future it will be possible to pay less attention to industry. In fact industry and services are closely interrelated. In particular the knowledge-intensive services provide a series of performances which feed into the R&D-intensive industries.

In the R&D-intensive industries, the cutting-edge technology has a considerably higher rate of growth than the high-level technology. However, the focus of the innovation activities and the technology exports in Germany has for a long time been on high-level technology. The proportion of cutting-edge technology is currently still so low that an appreciable structural shift will only be noticeable in some years' time.

German exporters achieve considerable success with high-level technology products. The foreign trade statistics are led by the automotive industry, followed by mechanical engineering. However, the chemical industry and pharmaceuticals, which in the past were very strong, no longer generate foreign trade surpluses.

Although Germany still has a strong position in terms of foreign trade, a long-term analysis shows that other countries are becoming stronger in the R&D-intensive industries, particularly in the German domain of high-level technology. This is already being reflected in a gradual decline in the foreign trade surplus in high-level technologies.

Research and development

Regarding the proportion of research and development in the gross domestic product, Germany lagged behind the leading countries for many years, but in 2006 had again reached a level of 2.3 per cent, and had thus achieved a relatively good position in comparison with other large industrial countries such as France (2.12 per cent) and Canada (1.97 per cent). However, Sweden (3.2 per cent), Finland (3.5 per cent), Japan (3.3 per cent), Korea (2.8 per cent), Switzerland (2.0 per cent) and the USA (2.2 per cent) are still ahead of Germany. The distance to the target of three per cent by 2010 agreed by the EU member states in Lisbon is also still considerable.

Until the end of the 1980s, Germany's R&D expenditure relative to the GDP was about 30 per cent above the OECD average. This advantage had shrunk by 2005 to twelve per cent. This was due among other things to the growing R&D expenditure of many smaller countries, which invest preferentially in advanced technology. In Germany, the research-intensity in most sectors of cutting-edge technology has declined, with the exception of pharmaceuticals, for which the research intensity has increased further.

In high-level technology, the German dynamic also lags behind the international level. The most important exception from this trend is the automotive industry, which has considerably improved its position regarding the level of R&D expenditure (nationally und internationally). Research intensity in the chemical industry continues to decline steadily.

A remarkable trend is the increase in research and development in Germany's services sector, although in an international comparison there is still much catching up to be done. There has also been a considerable expansion in commissions placed with external research and development institutions, which can be interpreted as businesses concentrating increasingly on their core competence. Most R&D-orders are placed with other companies, but scientific institutions have also benefited greatly.

A phenomenon internationally and also in Germany is the increasingly pro-cyclical behaviour of companies regarding their R&D activities. For some years they have been increasingly orienting themselves towards short-term requirements. R&D seems in part to have lost its proactive, longer-term character. This could indicate that part of the increase in German R&D expenditure in 2006 was relating to the economic developments and was not structural in nature.

Increasing R&D expenditure

R&D expenditure by German companies in 2006 amounted to 51.98 billion euros, which represents an increase of 7.4 per cent over 2005. Whereas approx. 304 500 personnel (full-time equivalence) were employed in R&D in 2005, this rose to about 312 000 in 2006. The personnel level for 2007 is expected to be about 320 000. Company projections for R&D are also available for 2007 and 2008. According to these unconfirmed estimates, R&D expenditure for R&D in 2007 will have been 54.34 billion euros, and for 2008 will be 55.51 billion euros, with corresponding estimated growth rates of 4.5 per cent (2007) and only 2.2 per cent (2008).

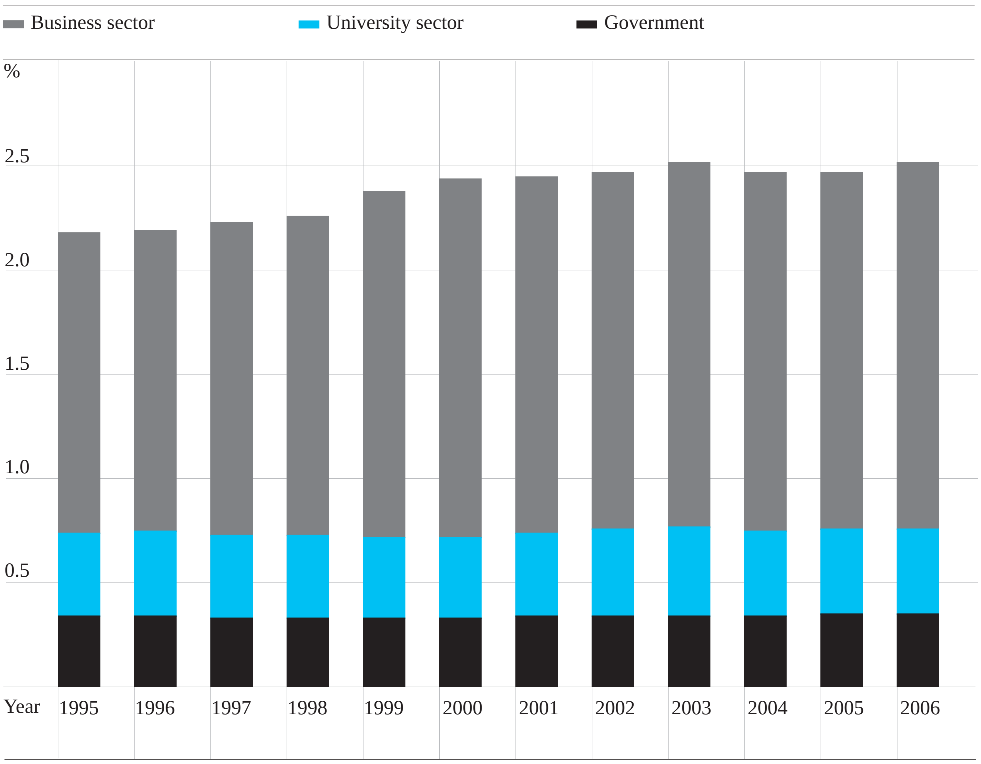
R&D expenditure of the companies developed better than expected in 2006 and totalled 1.77 per cent of GDP. Exact figures are not yet available for R&D expenditure in the university and the state sectors, but taking 0.76 per cent on the basis of 2005 as reference, overall R&D expenditure in 2006 increased to 2.53 per cent of GDP (Figure 01).

In an international comparison, Germany is therefore in the leading group of OECD member countries, but remains behind Sweden, Finland, Japan, Korea, Switzerland, and the USA. But Germany has a considerably higher R&D intensity than the average for the EU-27 member states, or than France and Great Britain (Figure 02).

The recent figures on innovations expenditure confirm these conclusions. German companies increased their innovations expenditure in 2006 by about 6 per cent to 115.5 billion euros.[7]

R&D expenditures in Germany as per cent of GDP

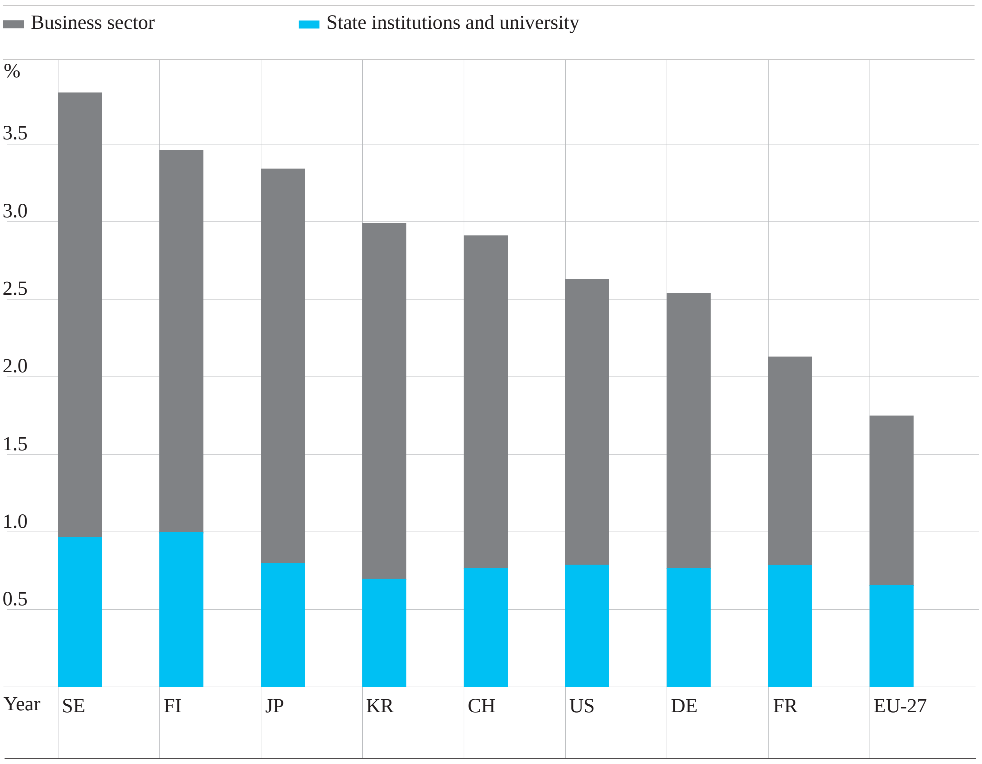
FIG 01



Source: Stifterverband (2008).

R&D intensity of selected countries 2006

FIG 02



Source: Stifterverband (2008).

Company revenues increased by about the same amount. The estimates of the companies for 2007 indicate a further increase of 5.5 per cent, and for 2008 they expect a lower increase of two per cent.

In all, it seems that there was healthy growth in 2006 and 2007, both in R&D expenditure and also in innovations expenditure. However, we view the projected figures for 2008 with some concern.

Commitment to the three-percent target

The German federal government has variously expressed its commitment to the EU's Lisbon target of achieving an R&D intensity of three percent. The three-percent target acts as a clear signal, and with their decision the German government underlines the importance of research and innovation. However, it will require considerable efforts from all sides if the target is to be reached.

The projections for R&D and innovation expenditure for 2008 indicate that additional impulses will be needed in order to reach the three-percent Lisbon target. The German government estimates that R&D expenditure by state, universities and business will have to be increased to approx. 79 billion euros in 2010. We calculate that some 70 000 additional R&D personnel will be needed.[8] Given that there is already a shortage of skilled personnel, it is clear that achieving the three-percent target will not be easy. In the following sections we present various ways to increase R&D expenditure and to avoid emerging bottle-necks in the availability of skilled personnel.

Research and innovation in small and medium-sized enterprises

Small and medium-sized enterprises (SMEs) do not carry out much of the research in Germany, but they play a central role in the dissemination of innovations. The involvement of SMEs in on-going research is therefore an important indicator. There has been a clear reduction over the past decade in the R&D involvement of SMEs (D 3 – 3). This also affects the innovation expenditures of the SMEs, which are also in decline.

At the same time, the level of state subsidies for companies in Germany has halved since the start of the 1990s, which has also impacted on the research involvement of SMEs. This declining state involvement corresponded to an international trend. In many OECD countries, however, there has been a renewed increase in support for industrial R&D since the mid-1990s, especially through indirect instruments such as tax rebates. These are of benefit above all to SMEs, and they increase the volume of R&D subsidies considerably. Possible effects of the increased support for R&D in Germany since 2006 are not yet visible in the statistics.

Innovator rates and innovations expenditure

The proportion of companies introducing new products and processes, which had declined consistently from the year 2000 onwards, is now increasing slightly again. The situation

BOX 05

Innovation and imitation

Successful innovations are soon copied. From the point of view of the innovator such imitations reduce the private earnings from an innovation. But imitation processes also have certain macroeconomic benefits, for example preventing the development of monopolies. Dynamic competition is not imaginable without both innovation and imitation.

is similar for the revenue generated with innovations. Like R&D expenditure, innovation expenditure is procyclical. In times of economic growth it tends to increase, and then declines again in economic downturns. It is also noticeable that since 2000 there has been a marked decline in the proportion of original new products among the innovations, which now more frequently involve imitations or have a more reactive character.

The innovation expenditure relating to services as a proportion of turnover is increasing appreciably, which corresponds to the observation for research and development.

Patent applications

For patents with an international orientation, which have been increasing again in recent years, high-level technology predominates. The German share of patents in cutting-edge technology is small in global comparison, and has been declining since the year 2000. Germany has a strong position for patent applications in high-level technology, which it has been able to maintain. The numbers of applications in this field of technology in Germany are increasing to about the same extent as the overall figures for worldwide applications. Regarding high-level technology patents, Germany specialises primarily in automotive construction und mechanical engineering, whereas patenting in biotechnology, information technology and telecommunications is still much less important than in other countries.

New enterprises

New enterprises make an important contribution to economic competition. New, efficient companies replace older, less efficient ones. In Germany, both the relative numbers of new enterprises founded and the proportion of all companies closing down remained below comparable figures for most other countries. The structure of entrepreneurial activity in Germany is also less strongly directed towards research-intensive and knowledge-based sectors of the economy than in other highly developed countries. After the collapse of the New Economy, overall entrepreneurial activity in this sector weakened. With fewer new enterprises being set up and fewer closures, the innovation pressure on existing companies in Germany is comparatively low, with fewer innovation impulses. Relative to the size of the economy, fewer innovative ideas are tested for their market relevance than in many other industrialised countries.

Training and qualifications

The innovation pressure in the knowledge-based economy has raised the demands on the qualification profile of the workforce; highly qualified personnel play a key role in innovation competition. The inexorable intensification of knowledge calls for advanced academic qualifications, and for high-quality vocational training in the middle layers.

Annually, an additional demand for up to 50 000 graduates is to be expected, not even allowing for any increase in demand generated by economic growth. In particular in the natural sciences, engineering and computer sciences this is leading to severe shortages, and will act as a constraint on innovation and thus also on economic growth.

The numbers of students starting university courses, which had declined steadily in all disciplines since 2003, began to rise again in 2007. Numbers of students are expected to continue to rise until 2012, boosted also by the shift from 13-years schooling to 12 years in many areas. However, in the longer term, demographic developments will lead to a reduction in cohort sizes. This makes it all the more important to reduce the excessive numbers of student currently dropping out of engineering and the natural science courses without a qualification.

Even now, the demand for suitably trained and qualified skilled personnel is considerably higher than the available supply. Given the long reaction times involved with measures in the educational sector, appropriate steps are urgently necessary.

Germany as a research location and German research in other countries

Germany is the second largest research location for foreign companies after the United States of America. In all about a quarter of the research in Germany is attributable to the subsidiaries of foreign companies.

Conversely, German companies carry out a quarter of their R&D at foreign locations. In the past, United States and Great Britain were the preferred location for the research and development work of German companies. Increasingly, research is now being carried out in Asian newly industrialising countries and in eastern European countries. The re-location of German R&D activities is currently rare, but will probably become more common in the medium-term. This is due less to wage differences than to the availability of specialised personnel.

The growing economic power of the Asian newly industrialising countries, in particular China and India, is meanwhile common knowledge. However, these countries are still often regarded as producers of cheap imitations which do not represent any real competition for the high-technology producers of the leading industrialised nations. The figures on publications, patents, foreign trade or R&D, however, show that these countries are making considerable efforts to provide large numbers of highly qualified personnel and are initiating rapid growth in all the sectors mentioned.

The newly industrialising countries now account for a quarter of worldwide expenditure on research and development, a doubling over the past decade. The patent profile shows that countries like China are increasingly orienting themselves towards high-level technology and even cutting-edge technology.

Summary

Germany is well positioned in many areas in research and innovation. This applies in particular for foreign trade with high-level technology products and the numbers of patent applications. Public and private expenditure for research and development is increasing again, and the innovator rate is stable at a relatively high level.

BOX 06

Equity and loan capital

Equity is the capital provided by the owners of a company plus any retained profits. The owners of the company are entitled to the earnings remaining after the payment of all liabilities to the employees, external investors and other creditors. Should the company become insolvent, the equity serves to meet the claims of creditors. In this sense, equity bears the risk of the company. Loan capital must be repaid after a specified period, and in addition interest must be paid. In order to ensure that loan capital will be repaid, banks require sufficient prospects of future company profits or the provision of securities. This means that young, innovative companies are often only able to draw on equity financing. The equity is regularly put up by the founders of the company or by investors (shareholding).

However it is important to note a number of critical points:

- The foreign trade balance for R&D-intensive products shows a negative trend, attributable to the growing international competition from other industrialised and newly industrialising countries.
- The increase in patent applications and in research and development activities has not yet led to a relative improvement in Germany's position, because corresponding activities have also been increased in other countries.
- The concentration on high-level technology has in the past been a central advantage for Germany over its international competitors. However, in the medium-term it will be necessary to shift the emphasis to cutting-edge technology. Such a change is taking place in Germany, but from a very low base and much more slowly than in most other countries.
- The Asian newly industrialising countries are very involved in high-technology and have meanwhile reached an impressive level. This is also a reason for further increasing the innovation activities in Germany.
- The numbers of new enterprises being established in Germany is relatively low in an international comparison. This applies in particular in the research-intensive sector and in knowledge-based services. In Germany, not enough research results and new ideas are tested on the market.
- A particularly grave problem for R&I in Germany is the growing shortage of qualified personnel. With the continual structural change towards a knowledge-intensive economy and a services society, the demand for specialist personnel is increasing. The qualification initiative finally started by the German federal government in January 2008 is therefore most welcome. The supply of highly qualified personnel will become an important factor influencing the choice of research locations for companies within the framework of globalisation.

This assessment of the situation will now be analysed on the basis of the financial, fiscal, and educational framework conditions as well as the Hightech strategy and the growth potential of the German economy.

CONDITIONS FOR FINANCING INNOVATIONS C 2

Equity essential for innovations

Adequate financing is essential for successful innovations, and in most cases this involves equity (Box 6). However, for various reasons, German companies have relatively low equity ratios – on average 11.7 per cent for medium-sized companies and 26.8 per cent for large ones.[9] This financing structure is considered to be a constraint on innovation.

Whereas the equity market is very important for the financing of innovations in Germany, in comparison to the size of the economy it is still underdeveloped.[10] Not only is the absolute level of the capital invested lower than in comparable European industrialised countries[11] – but also equity holdings are still inadequate in an international comparison. The result is that there are persistent gaps in the supply of financing for young, smaller companies.[12]

In view of the importance of equity for financing innovations, the fiscal framework conditions are of considerable importance both for the companies as well as for providers of loan capital – fiscal policies are thus always an element of innovation policy.

BOX 07

New enterprises

Innovation frequently involves setting up new enterprises. This is often the case if an innovation does not 'fit' into the organisational context of an established company, or originated in a university or a research institute. If the commercialisation of an idea requires the intensive cooperation of the researcher or inventor, then starting up a new enerprise can be an option. This is also favoured if there is the prospect of healthy earnings in the future.

Company tax reform 2008

With the Company Taxation Reform Act 2008, the German government intends to provide more fiscal equality, between businesses with differing legal forms, and provide long-term security for tax incomes of local authorities. Key elements of the reform are the reduction of the tax rates for companies from 40 per cent to 30 per cent and the introduction of a 25 per cent flat rate for the tax on income from capital assets with effect from 1st January 2009. The reform has received a mixed reaction from expert bodies. A positive element is that the tax burden on companies will be reduced and thus funds will be released for investments. However, the German Council of Economic Experts[13] sees problems in particular in the inadequate harmonisation between the two measures mentioned above. This will reinforce the existing distortions in favour of loan capital financing. Since in many cases innovations cannot be financed by loan capital, the intended positive effects of the reform may not be felt sufficiently by innovative companies.

Tax legislation discriminates against equity

German tax legislation treats equity worse than loan capital. When loan capital is used for investment financing, the interest paid can be booked as expenditure, reducing the taxable profit and thus the tax burden. From 2009 the provider of the private loan capital will only have to pay a flat-rate tax of 25 per cent on the interest received. In contrast, financing by means of equity is subject to double taxation. The company cannot deduct the investment income paid to the providers of equity from earnings before tax, but has to pay this from its profits. And although the company has already paid tax on the profits, the equity provider also has to pay tax on the investment income. In other words, the total tax burden on financing by equity is nearly 50 per cent.

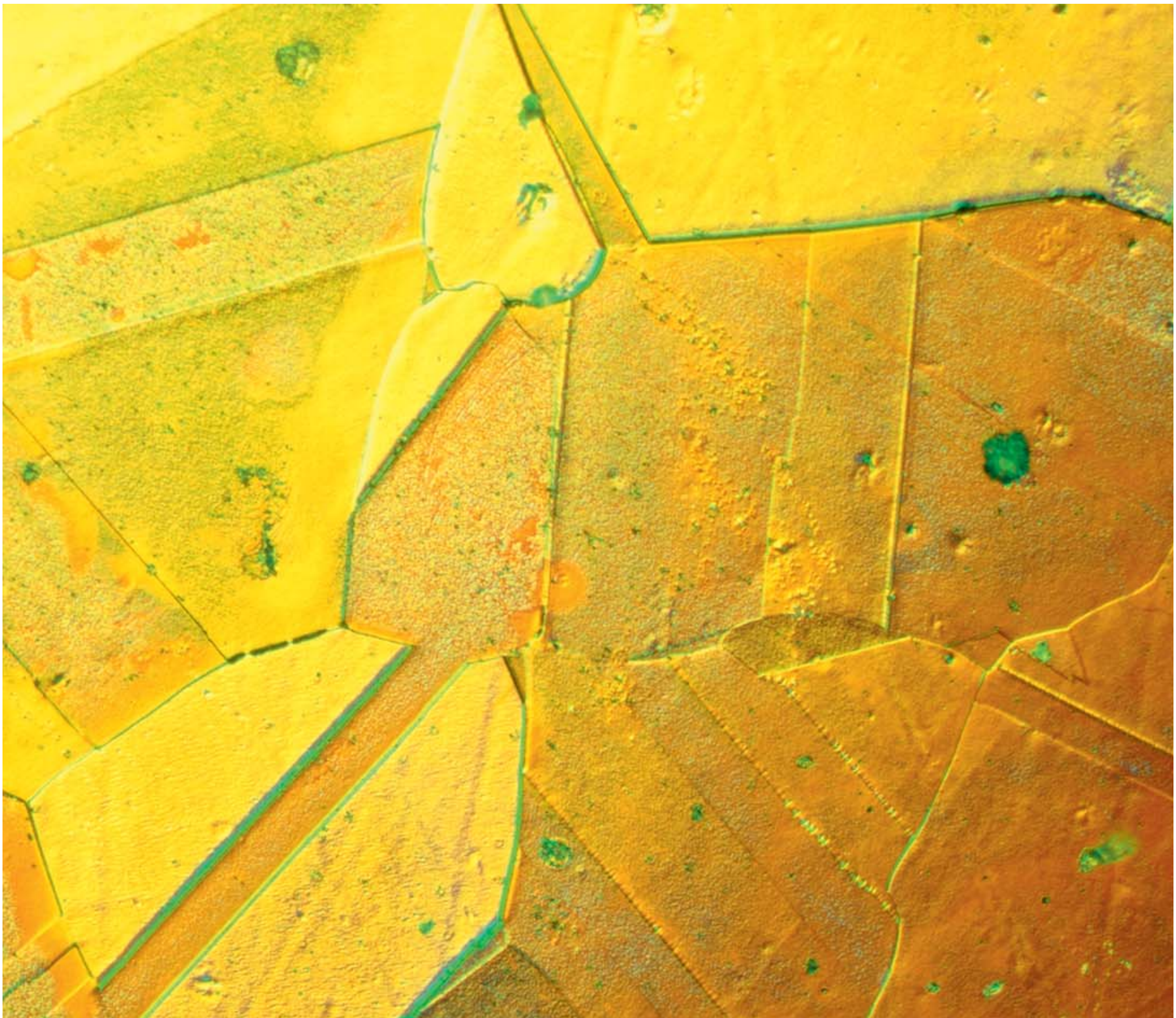
This asymmetry in the fiscal handling of loan capital and equity has long been criticised by leading bodies such as the German Council of Economic Experts[14] and the Academic Advisory Council at the Federal Ministry for Economics and Technology (BMWi).[15] The Expert Commission for Research and Innovation concurs with this criticism. Other countries also have an asymmetric treatment of equity and loan capital – but the effects are as a rule less because the tax rates are lower.

Asymmetric treatment of profits and losses

A further asymmetry is the treatment of profits and losses of innovative companies. Whereas the government partakes proportionally in all profits through taxation, any start-up losses are only partially allowed to be taken into consideration. The negative impact of this is felt in particular by smaller innovative companies.Their projects are frequently long-term, they involve high start-up losses, and in contrast to large companies they cannot be cross-subsidised by profits from other projects.

The regulation introduced in Germany in 2004 for the minimum taxation of profits means that in the first years of reporting profits a company cannot write these off completely against losses carried forward from earlier years. After reduction of a base sum of one million euros, they have to pay tax on at least 40 per cent of the profit. If innovative developments are very capital intensive they may very well incur initial losses which are considerably higher than the base sum, and the regulation is particularly harmful in such cases. In effect, the tax legislation increases the costs of financing for the very companies which have the courage to invest heavily over a number of years and to risk losses in order to realise profits subsequently.

An even more serious effect has been felt since January 2008. In international comparison, equity-financed German companies face considerable disadvantages because of the new, restrictive provisions of Section 8c of the Corporation Taxation Act (KStG), which regulates the carrying forward of losses. The accumulated losses brought forward are lost if one shareholder acquires more than half the company shares within five years. This includes an increase in the share capital. For a holding of more than 25 per cent and less than 50 per cent, the accumulated losses brought forward are lost proportionally. But the financing of inno-



Microscopic image of a metal alloy

Gold foil

vative new enterprises and also the possible takeover of such companies, e.g. by strategic buyers, represents an important mechanism for technology transfer. The prospect of a profitable acquisition often provides investors with the incentive to invest in a start-up enterprise. In particular in highly innovative sectors with long incubation periods the new regulation leads to considerable disadvantages for Germany as a location. The tax system becomes a massive obstacle for innovative projects and companies.

As an example, biotechnology companies can easily accumulate losses of tens of millions in the first 10 to 15 years of their business operations and more than a quarter require several rounds of external investment to fund this. More than two-thirds also have plans to draw on external capital within the next two years.[16] On average, biotechnology companies go through a new round of financing every 2.4 years. In the course of such transactions, investors frequently acquire more than 25 per cent of the company through new share issues. Although the company retains its legal identity, it is not possible to carry losses forward, either in whole or in part.[17]

The original aim of the legislation was to put a stop to the fiscal misuse of losses. But the new formulation, in which situations such as those described for the biotechnology companies are treated as 'misuse', goes too far. A look at other countries shows that it is possible to make an appropriate differentiation between cases of misuse on the one hand and situations which are genuinely worthy of support on the other. Under the fiscal policy which has been adopted, the government participates in the profits of companies, while largely ignoring the losses incurred while establishing the company.

The current treatment of losses carried forward is illogical within the context of innovation, constraining risky, innovative activities of young and medium-sized companies and making Germany less attractive as an investment location in the long term.

EFI urgently recommends that the German government removes the fiscal impediments to research and innovation. An exception should be made to allow losses to be carried forward by innovative companies with a specified R&D rate – analogue to previous recapitalisation privilege under Section 8.4.3 of the Corporation Taxation Act (KStG).

Problematic framework conditions for private equity providers

Constraints on innovation not only affect companies, but also investors. In an international comparison, the framework conditions have been poor for external investors in Germany for many years. A central problem is the legal uncertainty about whether investment companies providing private equity are managing assets or are commercially active. In the case of asset management, taxes would only be payable by the holding companies providing capital, but not by the financial intermediaries. Many holding companies have meanwhile relocated outside Germany because of this lack of a long-term distinction between asset management and commercial activity.

This not only reduces Gemany's tax receipts, but is also detrimental to the new enterprises looking for finances. Few investment funds are now established in Germany. This has negative consequences for the supply of capital for German SMEs and new enterprises because the geographical proximity between an investment company and its holdings is important in order to be able to provide support and act locally without complications or additional costs, e.g. travel expenses. This negative development affects in particular the early-stage financing market, which is already underdeveloped.

We recommend that the approval of the status as an asset management fund should in the long-term be harmonised with international standards.

New legislation in 2008 offers few improvements for venture capital

In 2008 the Modernisation of the Provisions for Capital Holdings Act (MoRaKG) is expected to come into force. This represents a step towards improving the equity financing of companies by venture capital but it is so restrictive that only a fraction of the market will benefit.

The proposal introduces provisions for venture capital providers which will allow their classification as asset management funds and provides for appropriate carrying forward of operating losses. However, the venture capital must be provided for enterprises which are less than ten years old and are not listed on the stock exchange. Other restrictions are that they must not have holdings in older companies and have a net equity of less than 20 million euros.

It is not possible to determine exactly how many companies would be affected, but recent investigations estimate that some 50 per cent of venture-capital financed companies have more than 20 million euros of equity.[18] It is likely that funds, which focus in particular on capital-intensive, future-oriented industries, also invest frequently in companies above the maximum level, and thus will not benefit from the legislation in its proposed form.

An additional geographic requirement that financed companies must be located in the European economic area is very restrictive and limits mobility. In order to receive the privileged status intended by the legislators, no more than 30 per cent of the investment volume of the fund may be in holdings which are not in conformity with this law. This can lead to the investor being excluded from the privilege directly or retrospectively. But experience shows that relocations may become necessary because of fluctuations in the economy or as a result of mergers and acquisitions.

It is unlikely that the new legislation will positively affect companies investing in innovations. The commission therefore recommends that the very restrictive scope of the proposed law should be altered to achieve an effective and internationally competitive promotion of equity holdings in SMEs which are not listed on the stock exchange – particularly those with high R&D expenditure. This should include an increase of the equity level from 20 million euros to 50 million euros, as well as the cancellation of the geographical limitations and the requirement that the financed companies are not allowed to acquire holdings in older companies.

In the early phase, technology-oriented new enterprises are often financed by business angels, who provide capital and their valuable expertise and in return acquire shares in the company. In comparison with the Anglo-Saxon countries, Germany is way behind in terms of the numbers of business angels and investment volumes.[19] There are a series of reasons for this. One important reason is certainly that – in contrast to Great Britain, the USA and France – Germany still offers no effective fiscal privilege for such investments.[20]

We recommend defining tax advantages for business angels which encourage their investments in growing new companies.

Venture capital and the three-percent target

Against the background of the three-percent target adopted by the German government, it is important to consider the possible contribution of the venture capital industry. Venture capital is offered to companies with strong growth rates. These companies frequently also have high research intensity. The research and development expenditure per employee in companies financed by venture capital is much higher than the average of the 500 companies with the highest research expenditures in the 25 EU member states.[21] Venture capital could therefore make a contribution to achieving the three-percent target. This has not yet been given sufficient consideration in the political discussion.

An interesting scenario would involve improving the German framework conditions for venture capital in order to attract foreign investors. Put simply, achieving the three-percent target would be financed in part by foreign institutional investors. Even if the 'only' success were to stimulate German institutional investors to take greater interest in the venture capital market in Germany, funds would be mobilised for financing R&D which are currently not available.

R&D AID THROUGH THE FISCAL SYSTEM C 3

R&D promotion in the fiscal system in the EU and OECD member states

Whereas German tax laws in important areas constrain innovation activities, the majority of OECD and EU member countries provide explicit fiscal stimulation for commercial R&D. These countries use tax credits or tax allowances which are coupled to the level of the R&D expenditure. SMEs often receive preferential treatment under these measures, and in some countries the support is targeted exclusively towards SMEs. Germany makes no use of this possibility.

Fiscal aid instruments for R&D were first tried in OECD member countries in the 1970s and 1980s, with mixed success. Meanwhile, 20 of 30 OECD member countries and 15 of 27 EU member states have implemented measures to aid R&D through fiscal incentives. Evaluation reports suggest that the initial difficulties encountered with the various measures are now under control.[22] Using the tax support instruments, the R&D costs in many of these countries have been considerably reduced.[23]

Options for fiscal R&D aid

The systems used by various countries differ considerably, both in terms of the level and also the nature of the support. With tax credits, the company is able to cut tax payments or claim for a refund; systems of this type are operating in the USA, Korea, France, the Netherlands and Canada. Tax allowances mean that the income before tax is reduced; this form of state aid for R&D is used by Australia, Austria, and Great Britain.

R&D promotion through the tax system - selected OECD member countries 2004/2005 TAB 01

Countries with tax credits	Countries with tax allowances
France	Australia
Ireland	Belgium
Italy	Denmark
Japan	Great Britain
Canada	Austria
Korea	Hungary
Mexico	
Netherlands	
Norway	
Portugal	
Spain	
USA	

Source: Warda, J. (2006), p.15.

In many countries, the fiscal R&D aid for SMEs and new enterprises is more attractive than for large companies. In some countries the level of tax aid is not dependent on the level of

R&D expenditure of the company, but on its growth, which has the benefit of limiting drops in tax receipts. Table 01 summarises the types of regulation in force in various countries in 2004/2005.

Advantages and disadvantages of fiscal R&D stimulation

An advantage of fiscal R&D stimulation for companies is that it is available for R&D expenditure of every sort. Furthermore the aid can be accessed without a separate application procedure. Because the fiscal aid is an entitlement, it is something that the companies can plan with. The scope of fiscal R&D support is therefore likely to far exceed any subsidy programme requiring advance registration. In addition, a form of R&D aid anchored in the tax system also sends out an important signal for companies which are not yet active in Germany and make the location more attractive. The key advantage, however, is probably the avoidance of market distortions. With a fiscal R&D support system the government does not influence the contents and direction of the R&D, but reduces the costs of carrying out any sort of R&D activity.

A disadvantage of fiscal R&D promotion is that an immediate advantage is only felt if the company has generated a profit. Tax benefits which are carried forward are only of use to the company some time later. The aid then loses part of its intended effect. In Great Britain companies can therefore opt to receive a cash payment.[24] This is popular with growing innovative companies, where income streams are restricted in the early years of business.

Comparison with promotion by subsidies

As an alternative to tax credits or some similar fiscal arrangement, state aid for R&D can also be provided to companies in the form of an equivalent subsidy. However, this has the disadvantage that it requires a separate application system, which in Germany usually involves a project organising agency. In addition, the costs for communications and for monitoring the subsidy process can be considerably higher than when tax measures are used. However, the exact administrative costs of the two systems are unknown. It would be of considerable interest to compare the costs of project organising agencies responsible for R&I promotion programmes with those of the tax administration. Both types of support are open to abuse, and in the case of fiscal R&D support this can be checked by means of company audits. In the case of subsidies, supervision is the responsibility of the project organising agency.

Encouraging results from evaluation studies

The effectiveness of R&D support through the tax system has been demonstrated in various reports. The majority of studies indicate that in the long-term a fiscal promotion system generates R&D expenditure at about the level of tax concessions.[25] Other OECD and EU member countries have demonstrated that effective promotion by fiscal measures is possible and that appropriate economic arrangements can be made. The evaluation results can also be used to estimate the approximate extent of fiscal R&D aid. In order to provide greater incentives for more R&D expenditure by companies amounting to 0.2 per cent of GDP, a financing volume would be required of about the same amount (in 2006: 4.64 billion euros). However, these are very rough estimates and more precise figures can only be obtained by taking other parameters into account. Generally, however, fiscal R&D support can represent an important contribution towards achieving the three-percent target.

Necessary arrangements

A series of economic and legal questions have to be clarified when arranging a system of fiscal R&D support. These include defining the R&D expenditure covered by the fiscal aid, deciding the form in which the fiscal aid should be offered, whether the aid should be provided to promote new R&D or support existing work, and also the level of the aid. Furthermore, there are also complex legal questions concerning the compatibility with European Union state aid rules and the judgements of the European Court of Justice regarding territorial limitations. Since the European Commission has a positive attitude to fiscal promotion measures, we expect that any legal problems can be solved.[26]

Declining innovation contributions by small and medium-sized enterprises

Analysing the available reports, we conclude that a declining proportion of R&D expenditure is attributable to SMEs. The proportion of the enterprises introducing innovations has also declined over the medium term. The R&I activities of the German economy are concentrated increasingly in the large companies. These medium-term trends are not altered by the fact that there is an observable increase in the level of R&D activities at the present time.

State aid for R&D has in the past only been used by a relatively small proportion of SMEs in Germany. Survey results show that the proportion of innovative companies drawing on one of the various forms of R&D support is the lowest of all the EU member states studied. In addition, the difference between the participation rate of SMEs and that of large companies is more pronounced in Germany than in the other EU member states.[27]

Selective support makes sense if the aim is to aid projects or R&I in areas of particular importance for the economy as a whole. However, if the policy aim is to increase the general R&D activity of German SMEs and thus indirectly boost also the innovator rate, then a high level of selectivity is not necessarily advantageous.

New research aid for small and medium-sized enterprises

The decline in the innovation contributions by SMEs is very worrying. The German government has therefore decided to increase the innovation aid for medium-sized companies (*Mittelstand*) by ten per cent every year. Many observers have criticised the fragmentation and variety of the programmes, and in response they are to be brought together in the new 'Central Innovation Programme *Mittelstand*' (ZIM). In addition, SMEs involved in R&D activities in cutting-edge technology shall be offered easier and quicker access to state aid measures within the framework of the *SME-innovative* initiative. This will initially cover fields of technology such as biotechnology, information and communications technology, optical technologies, and nanotechnology. Projects will also receive support in the fields of production technology, and resource and energy efficiency. The provision of support for cutting-edge technology in SMEs by means of such measures is in principle to be welcomed. Such state aid programmes do not represent a substitute for a system of broad fiscal support for R&D, but supplement this.

Another interesting developing introduced in 2007 as part of the Hightech Strategy is the 'Research Premium', which is intended to provide additional incentives for the increased cooperation of universities and research institutions with business, in particular with SMEs. The research premiums are paid to universities and research institutions which carry out

R&D-commissions from SMEs. They cover 25 per cent of the costs of the order. The outcome has not yet been evaluated and the measure is currently only due to continue until 2009. Increased cooperation between universities and enterprises is a positive development (cf. C6). However, care should be taken that the research premiums do not introduce distortions to the disadvantage of private institutions providing research services under market conditions.

Recommendation

We welcome the measures adopted by the German federal government to streamline and expand the promotion of SMEs. However, it is doubtful whether the existing measures alone constitute a fully-formed strategy to support R&I in medium-sized enterprises. In order to establish a simple form of R&D state aid for companies in Germany which will allow long-term planning, we advise that fiscal R&D-measures should be developed like those which have meanwhile been successfully implemented in many OECD member countries. In view of the declining innovation contributions of SMEs in Germany, preferential aid for SMEs seems advisable. This would also be appropriate for other reasons. Financing restrictions and the above-mentioned asymmetries in the treatment of equity capital and loan capital have an impact in particular on SMEs and new enterprises. If appropriately structured, broad support for R&D through the tax system could represent an important addition to the targeted R&D project aid, which should still be provided for specific cases. The two instruments could complement one another. In addition, fiscal R&D support could provide an important impulse for achieving the three-percent target.

C 4 EDUCATION, THE LABOUR MARKET AND INNOVATION

In the globally-integrated society, knowledge is being generated, distributed, used, and devalued with increasing rapidity. This brings with it the growing need for constant technological and institutional renewal and innovation. In the current knowledge society, products with shorter life-cycles are growing in significance, and knowledge-intensive services are becoming increasingly important for the economy.

Education, vocational training, and further training – in other words forms of human capital – are becoming increasingly important for innovations. The expansion of communications and information technology and the associated modern forms of organisation in companies bring with them changes which exert a considerable influence on the availability of new recruits and the demands on the labour market. Employees need to have a higher and broader qualifications profile as well as key soft skills such as team and communications abilities.

Innovation and qualifications are in a dynamic interrelationship.[28] Innovations have serious implications for the levels of qualification required, and at the same time the level of qualification plays a key role for the innovation process. Innovation and the effective use of new technologies are not possible without education.

The importance of education, vocational training and further training for the innovation process is indicated by the fact that all indicator systems (see Box 08) to determine the innovative ability of a country always includes corresponding parameters. But whereas Germany ranks highly for various criteria such as the transfer into production or networking between companies and research institutions, in the field of education, vocational training und further training Germany is way behind the leading group.

BOX 08

Composite innovation indicators

It is not easy to register the complexity of innovation processes, particularly for a comparison between countries or over time. The complexity can be reduced by forming composite indicators – such as the 'European Innovation Indicator' of the European Commission[29] or the Innovations index of BDI, Stiftung Telekom, and DIW.[30]

Rankings on the basis of an interest-led selection of indicators can vary considerably, and they can be more than misleading. Without specification of the underlying complexities there is considerable scope for manipulation by means of selection, weighting, and aggregation. We therefore generally avoid using composite indicators.

This is a bad sign for the innovative potential of Germany in the medium and long-term, because education und vocational training play a lead role for innovations. The full consequences of the low levels of education, vocational training, and further training will only become apparent in some years time. Then, however, the low level of education will also result in deteriorating innovation performance. Well-educated specialists are a necessary precondition for innovations, both for inventions and for the implementation of innovative products and marketable services. If specialists are not available, then the entire innovation system in Germany will suffer.

Germany faces considerable challenges. Problems which are becoming obvious today will grow rapidly in importance in the coming years as a result of the demographic development and the significant changes in the skills requirements.

Threats for the innovation location Germany – Stagnating levels of education and poor further training

Educational expansion in Germany has come to a stop and for more than a decade there has been education stagnation. The proportion of an age cohort attending upper secondary schools (*gymnasium*) and obtaining the qualifications required to go on to higher education has hardly changed since 1995, and is about 32 per cent. The proportion of school students attending general secondary school (*hauptschul*e) has remained at 23 per cent over the past ten years.[31]

It is difficult to compare national school systems on the basis of the educational qualifications, and as a result the abilities of school students are increasingly being measured, for example in the Programme of International Student Assessment (PISA). Since the year 2000 this has been comparing the abilities of 15-year-olds from all types of school in reading, mathematics, science, and other topics. For the sake of simplicity, the following figures refer only to reading comprehension, but the results differ little from those for mathematics and other skills. A comparison is made between the results for the group of the competency rich (PISA-Level 5), and the competency poor (below PISA-Level 2), using absolute definitions in both cases.

Fewer than ten per cent of the 15-year-olds can be classed as competency-rich, against more than 20 per cent who are competency-poor. In the course of three surveys over six years there have hardly been any changes. Over-represented in this group are: boys, children from socially disadvantaged strata, and children with a migration background.[32] It will be difficult to integrate most of them in the labour market permanently, in particular in areas with a high innovation dynamic. An international comparison shows clearly that things can be different. In other countries, such as Finland or Korea, the proportion of competency-rich is about 20 per cent, while there are less than five per cent competency-poor. These differences point to considerable challenges, while at the same time highlighting a large unused potential.

The proportion of those with poor levels of education must be drastically reduced if a pool of people is to be available in future with the necessary propensity for vocational training or further education. It can no longer be tolerated that 20 per cent of all school-leavers still have considerable deficits and will not be able to take part in innovations. At the same time, work is also needed to achieve a significant increase in the proportion of those with higher levels of education.

In order to achieve this goal it is important not to address measures only at the schools and universities. The promotion of innovative ability in Germany, which in the end comes from well-educated individuals, requires consideration of the development of abilities, and this involves starting early in life. The quality of child care should be increased and more all-day schools need to be set up. This would make it easier for both parents to enter into employment and also fit in better with the steps being introduced to shorten secondary education by one year. Competition between schools improves the performance of the students, and this requires a transparent record of school performance.[33] In addition, the allocation to one of three types of secondary school at a young age often leads to a number of errors being made.

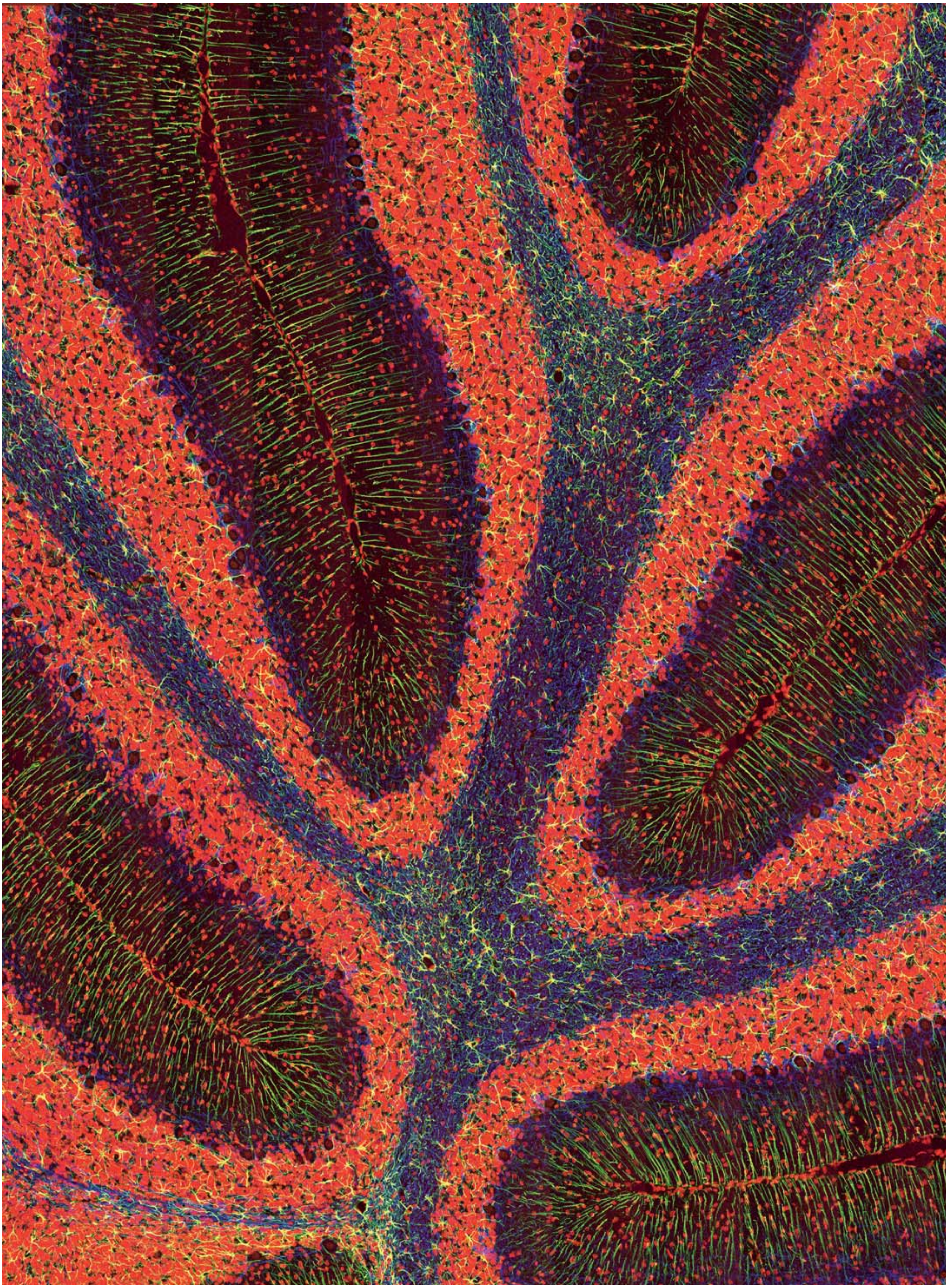
In additional to school education, steps also need to be taken for vocational training. The low proportion of school students in Germany going on to higher education has already been mentioned. But there has also been a decline in the proportion of 18-21-year-olds participating in the dual system of theoretical and practical vocational training, from 64.1 per cent (1993) to 53.6 per cent (2006). In contrast to the declining proportions of students and those signed on for vocational training, there has been an increase in the proportion participating in the so-called transition system, which does not lead to a full vocational qualification. In addition, the numbers of repeat applicants for apprenticeships after one year have been increasing successively. All in all, the fear is that the stagnating proportions of students and the vocational training rates will have a negative effect on the innovative potential, on the one hand because too few people will be available to develop the innovations (above all university graduates), and on the other hand there will not be enough people who can cope with them (people with vocational qualifications). In future it will be important not only to have a higher proportion of people going into higher education[34] but also to minimise the numbers who have not acquired some vocational qualifications.

Further training measures are also important. In Germany, only twelve per cent of all employees participate in further training over the course of a year. In the Scandinavian countries, the USA, and Switzerland the level of participation is three times higher. And when it comes to the number of hours invested in the further training, Germany is once again way behind in an international comparison (OECD, 2007b). The proportions taking part in further training are particularly low for those who have a poor level of education and for older employees. The special programmes offered by the Federal Labour Agency are only infrequently drawn on by the enterprises (IAB, 2007a). It has rightly been remarked that the German companies are themselves partly to blame for the creation of the shortage of specialised personnel.

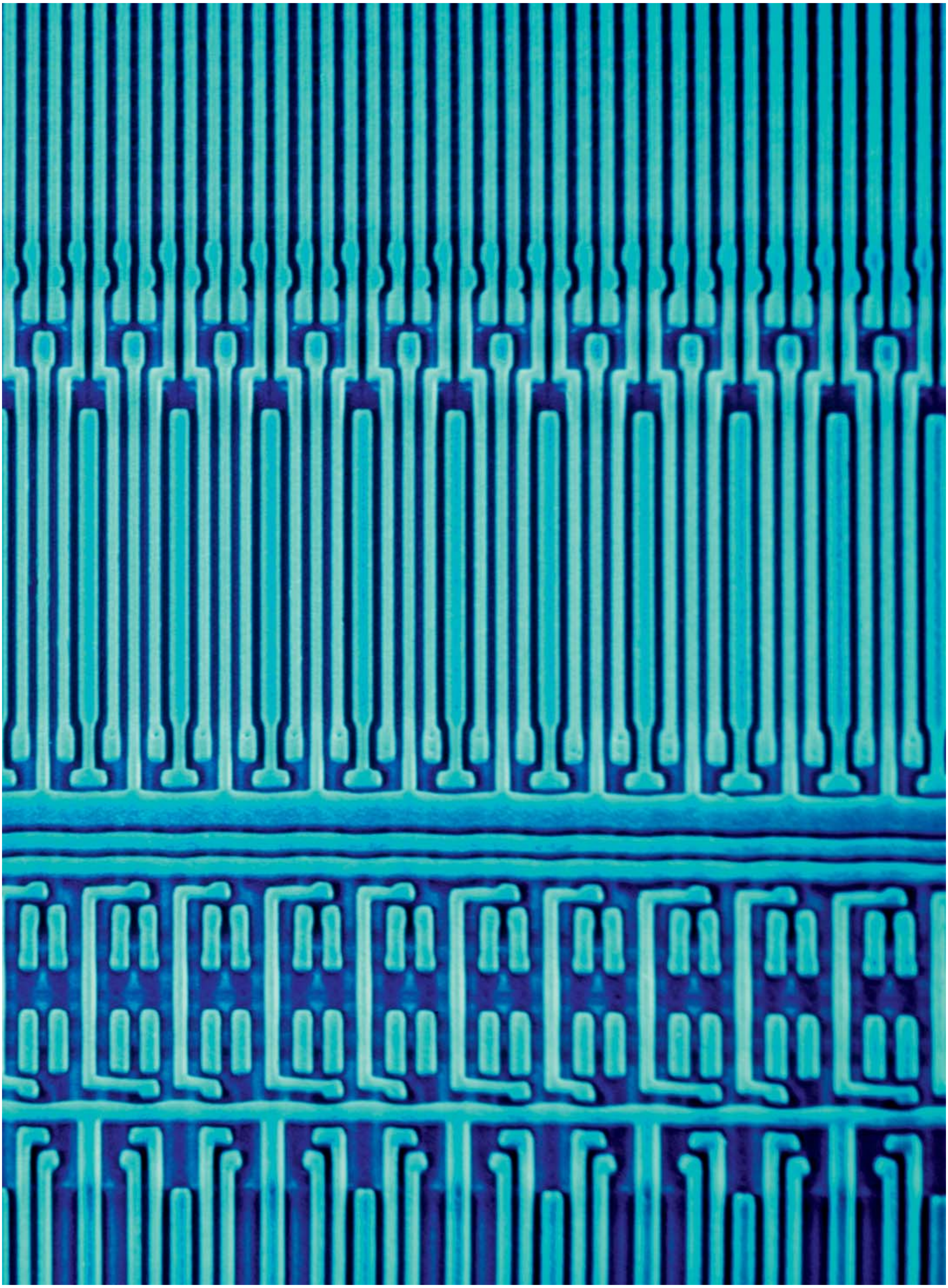
Employers and employees in Germany should increasingly regard further education as an investment in the future, as has long been the case for example in Finland, Sweden, Denmark, the USA and Switzerland. Measures for further training should be a key element in tariff agreements negotiated between employers and employee representatives. Knowledge is becoming outdated increasingly quickly, and people will find themselves working longer. Employers and employees can no longer rely on what they learnt the first time round if they want to keep up with the global competition. We therefore regard the increase in the rates of further training as essential for innovation in Germany.

Education problems exacerbated by demographic developments

The demographic development of Germany has significantly changed the relationship between old and young. At the end of 2005, 19.3 per cent of the population were older than 65 years, 60.8 per cent were aged between 20 and 65. By 2050 only about half the population will be of working age and a third of the population will be older than 65. A wave of well educated personnel will be going into retirement in the coming years without sufficient numbers of replacements with the same levels of education. In other



Structure of the cerebellum



Surface of a microchip

words, even if the relative proportions of people with various levels of education remain constant (education stagnation), the demographic development will mean that the absolute number of well educated will decline. According to ZEW projections[35] in 2014 there will be a shortage in Germany of between 23 000 and 95 000 engineers and between 155 000 and 397 000 others with academic qualifications.

The ageing of the population indicates a second area in which action is needed. In future many people will be willing and able to work longer, and by no means only because they cannot afford to retire. With a longer working life, the necessity for continuous training is even greater. Phases of further training must be integrated in business organisations and included in life planning. This also means that additional further training must be offered by universities and the vocational training system, together with an increase in company budgets for further training investments. Taking time out for further training must become the rule rather than the exception. Only then will the reluctant attitude of many towards further training be overcome.

In addition to better vocational training and further training of the labour force, there are also opportunities for increasing the absolute number of well-trained personnel and thus supporting innovation in Germany, namely the increase in the numbers of women who are in employment and the relaxation of the work restrictions on foreign graduates from German universities, and finally the recruitment of well-trained specialists from other countries.

Increasing the rate of employment of women

The rate of employment of women in Germany is 66 per cent, which is rather low in an international comparison. The figures for the Scandinavian countries (76 per cent) and Switzerland (73 per cent) show how much unused potential there is here, also in view of the fact that women are on average better educated than men.[36] The recent introduction of parent benefits and extended day care provisions has provided important signals for an improved compatibility of occupation and family. However, women who have been away from the labour market for some time do not benefit from these measures. More incentives and further training provisions are needed in order to reintegrate these women in the labour force. We will return to this group in our next report.

Apart from increasing the general rate of employment of women, efforts are also required to increase the proportion of women, involved in research and development. Women are considerably under-represented in research science, which is an important field for innovation of (only 21.4 per cent). Parity is not achieved anywhere, but most countries achieve a rate above 30 per cent. The southern and eastern European and the Scandinavian countries deserve mention, in particular Portugal (44 per cent) and Slovakia (42 per cent).

Increasing the employment of foreign specialists

Another way to redress the shortage in specialists is through migration from other countries. The German federal government has recently made initial decisions to ease the employment of foreign specialists and to monitor the shortage of skilled personnel. Foreign students who graduate from German universities should in future also face fewer constraints if they wish to work in Germany.

Some 80 to 95 per cent of foreigners who graduate from German universities then leave the country almost immediately because their visa expires. Winning these graduates for the German labour market would seem to be very attractive, because they will mostly be well integrated and as a rule will have learnt German. Additionally, many of the foreign students study technical subjects – in 2005, a quarter (about 2 500) graduated in engineering. Their profiles would fit in well with the needs of the labour market.

Restrictions are to be relaxed on foreign engineers in fields which are in demand. However, the highly-qualified personnel who are not from EU member states must still exceed an earnings threshold of 85 000 euros per annum in order to receive a work permit in Germany.[37]

We recommend that these minimum salary levels should be lowered significantly. Even then it should not be expected that increased migration alone will solve the specialist shortages in Germany.

In the past, high bureaucratic barriers have made Germany relatively unattractive for highly-qualified immigrants.[38] This probably explains at least in part why the numbers recruited in the relevant target groups have hardly increased, despite various programmes which have been introduced.

A successful migration policy requires that migrants are integrated better than they have been in the past. Looking at people currently living in Germany with a migration background, it is shocking how many have very low levels of education and vocational training. In all, 17.2 per cent leave school without any qualification. This is 2.5-times higher than in the comparable German group. And only 23 per cent of young people with a migration background are participating in vocational training.[39] Other differences are also stark. Compared with their German peers, only half as many young people with a migration background attend upper secondary schools (*gymnasium*) and almost four times as many go to general secondary schools (*hauptschule*). These figures cannot be explained either by difference in the social status of the parents, or by performance. For the same school results and social origins, children whose parents were born in Germany have a 1.7 times higher chance of being recommended for the upper secondary level than children whose parents both have non-German origins.[40]

We recommend that efforts should be continued in Germany to recruit highly-qualified specialised personnel from other countries, while at the same time better use should be made of the existing potential in the parts of the population with migration background. The innovation system in Germany cannot continue to allow itself to neglect the potential of 15 million people.

Structural change is worsening the education crisis

In Germany, like in other industrialised countries, the economy is going through a 'double structural change'.[41] The growth in production in the industrial sector is modest in comparison with the services sector, and the employment balance has been clearly negative since the start of the 1990s. And in the manufacturing sector and the services sector, the knowledge- and research-intensive branches of the economy are expanding. The sectors which rely less on highly qualified personnel and modern production plant are tending to decline. In the recent past it has only been the knowledge-intensive parts of the economy which have been in a position to create new jobs (Figure 03). This development can be observed in almost all industrialised countries. The greatest losses in employment are in the processing industries, in particular the non-research-intensive industries.

Increases in value added and in employment in Germany are attributable solely to the research-intensive and knowledge-intensive sectors. Technological progress is at the expense of the proportion of employees with low levels of qualification, whereas the demand for highly qualified personnel is growing.[42] Above all, company-related services, i. e. research and development, market surveys and opinion research or IT-consultancy will grow considerably in importance.

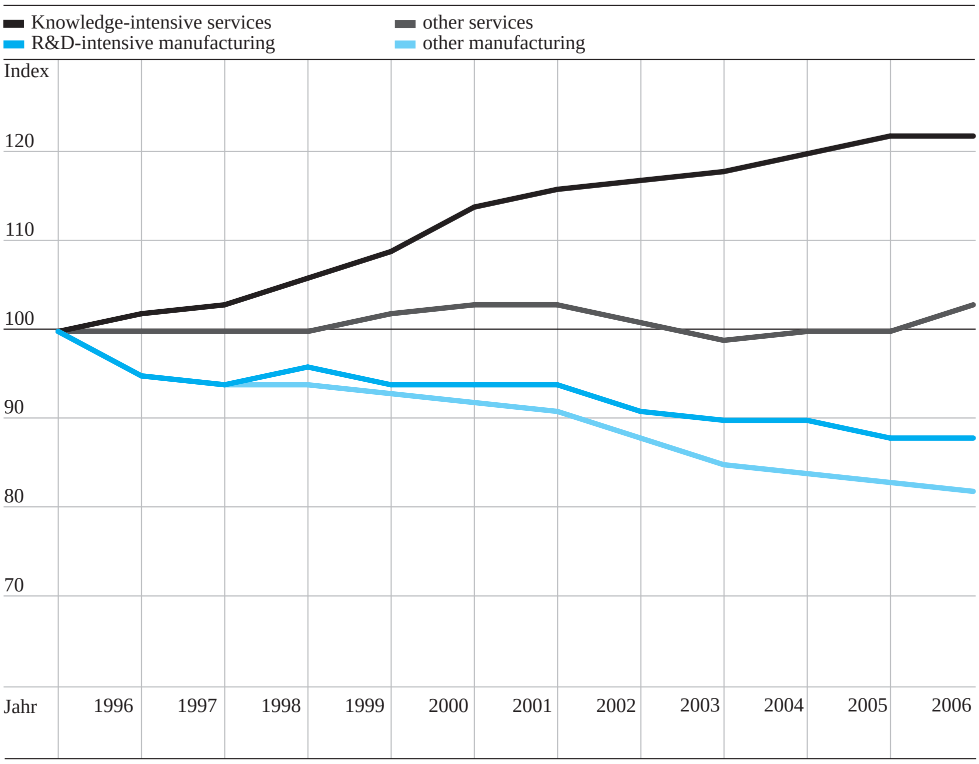
The discrepancy between supply and demand leads to a significant increase in personnel costs for knowledge-intensive industries and services. This brings with it the risk that German companies will increasingly move their innovation activities to other countries.

Accelerating the long march: improvements in education, training, and continuous education

Many of the processes described here cannot be influenced in the short term. The demographic population trends are unalterable for decades. It will not be possible to reverse the structural change in the economy in the coming years. This means that apart from the recruitment of foreign qualified personnel, the only other option is to improve the education, training and continuous education of the German population, in order to increase the potential of the labour force. The international comparison shows that considerably more young people can be led out of educational poverty and towards better educational achievements. It also shows that in other countries offers of further training are accepted and it is possible to maintain employees at their levels of skill for longer, and even to raise these. Increasing the pool of skilled and specialist personnel by extending the working life only makes sense if more emphasis is placed on further training. But because in Germany at present only five per cent of men and three per cent of women are still working over the age of 64 years, there are still considerable reserves here.[43]

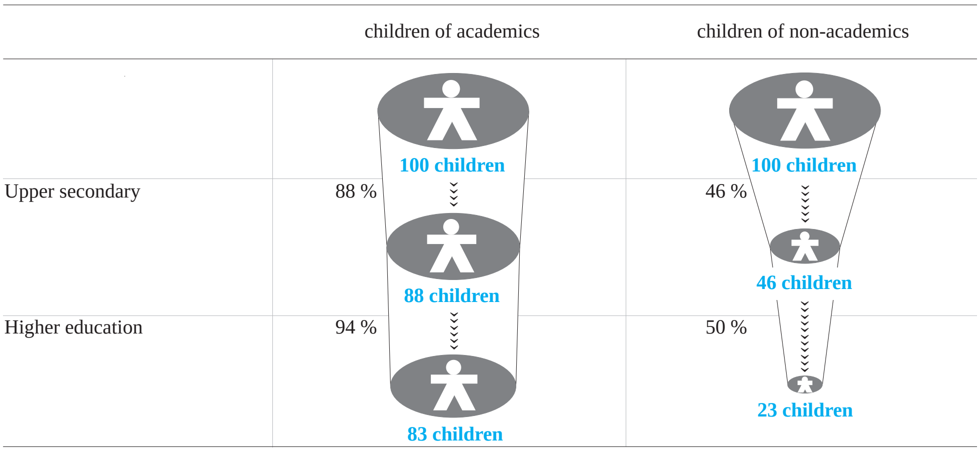
If Germany makes better use of the potential described above, this would also reduce the level of social inequality in access to education, which is relatively high in international comparison. Currently, only 23 out of 100 children from non-academic households go on to complete higher education. From families of academics it is 83 out of 100 children (Figure 04). Research has shown that this difference cannot be

Hours worked in various sectors in Germany FIG 03



Index: 1995 = 100. 2006 extrapolated from BBA statistics.
Source: EUKLEMS Database, Estimates in Belitz et al. (2008b). Calculations by DIW.

Social background, school attendance and higher education in Germany FIG 04



Source: Data from BMBF 2007b, our presentation.

explained solely by the different abilities of children when they start school or at the time of their allocation to one of the three types of secondary school in Germany. In order to receive a recommendation for the upper secondary level, children from the lower social strata have to demonstrate considerably higher abilities than children with a better social standing.[44] Furthermore, socially disadvantaged strata overestimate the costs of education, under-estimate the probability of success, and are likely also to be too pessimistic about the benefit of a given qualification, from lack of knowledge.[45] Therefore it is important also to work through the schools and not to rely on the parents.

The qualification programme of the German government, 'Upward mobility through education'[46] offers various proposals. Day care shall be made available for 35 per cent of under-threes by 2013, and a training initiative started for 80 000 small group child-minders. Funds shall be made available for universities in a 'University Pact 2020' to accommodate 90 000 new students by 2010. Grants will be made available for vocational trainees who achieve excellent qualifications. The central university placement agency (ZVS) is to become a service agency in order to provide more transparency about course places and to balance supply and demand. BMBF will work with foundations to establish regional further training structures. This initiative is to form part of an alliance of national, regional, and local governments with social partners. Also the Federal Labour Agency will monitor further training together with other actors on the labour market. Extensive measures will also be adopted in the field of dual theoretical and practical vocational training.

In order to strengthen Germany as an innovation location, the average level of education of the population must be raised. This will only be possible if early attempts are made to reduce the considerable differences arising from social origins and migration background. More emphasis will have to be placed on preventive educational policy, the deployment of social-pedagogues, and on teaching in small groups. This costs money, but it is better spent at this early stage than on 'repair measures' at a later stage or on social support for those who have not found a way to a life of gainful employment.

The initiatives of the German federal government to provide more and better crèches and kindergartens are to be welcomed. Another important step is the introduction of all-day schools, with a broader curriculum being taught in the afternoons. It will not be possible to increase the levels of employment of women in Germany unless provisions are made to care for children and young people through the day. The current school system is still largely reliant on mothers supervising homework and taking responsibility for the integration in sport groups and music lessons. But with the secondary school being shortened by one year, cuts have been made in subjects such as music, ethics, sport and art, in which the key competencies are taught which will be needed in the knowledge society. All-day schools will also be valuable because they offer the extra hours needed for these subjects.

In addition to the early streaming between school types in the German system, another problem is that the general secondary school only goes through until the ninth grade, which is not sufficient. The educational demands on the individual have risen in the modern knowledge-oriented society and can not be covered in such as short period. In addition, in some regions and cities the general secondary schools have become a collecting point for children from socially-disadvantaged backgrounds and with a migration background. As a result of this, some German *laender* have now changed to only two types of secondary school.

We also urge that universities be expanded. This cannot be a cost-neutral measure, and in addition to the federal and state governments business must also make contributions. An internati-

BOX 09

The Hightech Strategy of the German federal government – a new approach

In August 2006, the German federal government introduced a new approach to the integration of innovation support across all federal ministries. The Hightech Strategy adopts a completely new orientation for R&I policies. Particular attention is paid to the mastery of complex technological systems and the orientation to markets. The goal is to maintain and extend Germany's position in international innovation competition.

The Hightech Strategy defines five cross-sectional activities, namely science-business cooperation, new enterprises, dissemination, international cooperation, and human resource formation. At the centre of the efforts are 17 fields of innovation: Health and medicine, security, plants, energy, environment, information and communications, traffic and transport, aeronautics, astronautics, optics, materials, production, maritime technologies, services, nanotechnologies, biotechnologies, and microsystems engineering.

The strategy focuses on selected fields of innovation. A key element is the inter-departmental formulation of R&I policies, the increased market orientation of R&I and a concentration on the optimisation of the framework conditions. Responsible for the Hightech Strategy in the Federal Government is the Federal Ministry of Education and Research.

onal comparison shows that Germany's expenditure of 1.1 per cent of gross domestic product (GDP) for tertiary sector education is very low. In particular only about 0.1 per cent of this is attributable to private expenditure. The comparison with the USA is instructive: public expenditure for this sector is 1.0 per cent, but the private figure is 1.9 per cent, giving a total of 2.9 per cent. And in Korea out of a total of 2.3 per cent, public expenditure is 0.5 per cent and the private contribution 1.8 per cent.[47] Politicians should find ways to establish new forms of financing in Germany, in particular through more foundations. Enterprises must also participate more, because they have a high benefit from the development of student human resources.

IMPULSES FOR THE HIGHTECH STRATEGY C 5

Strengthening cooperation between government departments

With a complicated federal research and innovation system, it is not always easy to adapt to the dynamics of EU developments and globalisation. Therefore there are some coordination problems in Germany which need to be addressed by policy makers. The intention of political and business forces to make a bold step towards strategic renewal often comes up against a reality of narrow perspectives and institutional fragmentation.[48] Innovation topics have frequently had a hard time finding a platform, and there are no links between disparate forums such as research policy, health, traffic and transport, or agriculture. For the first time, the Hightech Strategy addresses a range of fields with its R&I measures. However, this requires improved coordination between the departments of the German federal government and the *laender*, for which only the first steps have been made.[49] In addition, increased harmonisation is needed at the level of the European Union.

More focus with the Hightech Strategy

As a result of the specific situation in Germany after World War II, the state aid policies of the federal government have taken a different course from those in many other western industrialised countries. There was an initial core of institutional promotion, and various new support instruments were added over time without completely removing the existing ones.[50]

The innovation policies in the USA and in many other countries are generally mission-oriented.[51] State aid is provided with the aim of achieving an ambitious goal. In contrast, the

German model has in the past involved a broad approach. Under the subsidiarity principle, any high quality research and development task deserves state support if it would not come about only through the self-regulated cooperation of the actors involved. Germany is one of the largest economies in the world, and has grown further through the unification of east and west, so that such a broad approach was justifiable, in contrast to the niche strategies adopted by smaller economies, such as the Scandinavian countries.

Against this background, the Hightech Strategy represents a change in policy. It attempts to adopt a selective approach and to concentrate the state aid on selected technologies and cross-sectional measures and thus to address sectoral innovation systems. However, we are not sure whether this can lead to the desired effects as long as the promotion priorities are selected on the basis of the specific innovations strategies. The optimum balance between focussing and a broad orientation requires further discussion.

Strategic further development of the Hightech Strategy

Concerning the further development of the Hightech Strategy, the question is how to make a systematic and well-founded choice of future-oriented topics. Here it is important to consider how the sectoral innovation systems on which the Hightech Strategy is based, and the targeted intermeshing of business and science in Germany, can be brought into effect at the EU level. The Hightech Strategy also involves contributions to the European Space Agency (ESA), aeronautics research, and other projects such as the Galileo positioning system. The topics agreed at EU level have noticeably large budgets.[52]

Forecasting methods for the further development of the Hightech strategy

German R&I policy-developers have been using various instruments of technology forecasting for more than 15 years, and in comparison with other European countries and the USA they have gained considerable experience. In the Foresight Process started in 2007 by BMBF, progress is being made on additional new instruments of technology forecasting, in particular in order to address broad topics and integrate these in a formal evaluation, and a wide range of methods have been implemented. However, it is not apparent how these appropriate and comprehensive forecasting activities are being coordinated with the other federal government departments involved in the Hightech Strategy, for example with some sort of road map. A systematic further development of the Hightech Strategy on the basis of such processes requires that all the departments should be actively involved.

We recommend employing an appropriate mix of technology forecasting instruments for the further development of the Hightech Strategy. It should be taken into account that this process will have to be inter-departmental. In addition, it is necessary to examine how viable and comprehensive the available methods of future research are, how much time they require and how inter-departmental evaluation problems can be resolved. The use of these methods allows actors in politics, business and society to see the criteria by which the next stages of the Hightech Strategy are chosen. We expect that this will result in private actors being more willing to participate financially in the Hightech Strategy programmes.

The budget of the Hightech Strategy

The Hightech Strategy has made it possible to boost the state funds for R&D considerably. Initial surveys[53] show than a satisfyingly large proportion of German companies are now aware of the Hightech Strategy. In addition, the companies surveyed said that they also

BOX 10

Innovative services

Services may be defined in terms of their immaterial nature in comparison with material goods or nominal goods (finances), or their transience (cannot be stored). The customer (individuals, companies, government) is also involved in the provision of the services, so that standardisation is difficult, e.g. the quality of a training course will depend on the activity of the individual participants.

It has therefore become usual either to list certain sectors which are included in the tertiary sector of services, or as a negative definition to include all sectors which do not belong to manufacturing industry, agriculture, or mining. These lists of sectors can vary considerably (wholesale and retail, transport, banking, insurance, computers, technical and commercial services, accommodation, education and training, health, culture, sport, entertainment, leisure, state activities, etc.).

'Services accompanying material goods' are defined as immaterial performances offered to customers or marketed by a manufacturer in additional to the material product. These services are related to the product and its innovative technology and are also traded on the market, with the innovative services being consumed at the time of the completion.

Depending on the sources, the definition of services differs. Innovative services are knowledge-intensive (see comments on 'Schumpeter Goods' Box 03).

wanted to increase their R&D expenditure, on average by seven per cent.[54] Germany would seem to be mobilising its innovative potential. However, the Hightech Strategy still seems to depend on vague budget projections for the cross sectional activities and specific innovation strategies. Of course, it was necessary at the start of the Hightech Strategy to draw on relatively crude budget figures, especially since these had to be drawn from the differing reporting systems of the federal government departments involved. But it is surprising that more precise details are not provided in the first progress report.[55] It is very important to be transparent about the extent of additional funding. Only in this way is it possible to demonstrate to the public and those directly involved how serious and ambitious the Hightech Strategy is.[56] Another very significant aspect is that it can act as a potential signal for companies which are not yet active in Germany.

EFI sees an urgent need to make public details of the budget, in order to show the past achievements and to continue these and spread them further.

Improving the services orientation

The value added by the knowledge-intensive services exceeds that of the R&D-intensive goods by nearly 14 per cent. Knowledge-intensive services meanwhile account for more than 30 per cent of value creation.[57] The services economy of the future will not replace the production of goods and in particular will not replace the production of 'Schumpeter goods'. Germany is specialised to a considerable extent in services which accompany material goods, as has been shown in earlier reports on technological capability.[58] This can be demonstrated by some examples. Environmental considerations have led to much longer working lives for products. But this means that production and disposal are being substituted for, in part, by a higher services input (repairs, spare parts, maintenance, etc.). Product-related services which extend the working life are a precondition and also a consequence of a lifecycle approach. Even imported products with a high portion of value creation gradually become domestic products as a result of the services, with important positive consequences for local employment. These ideas deserve due consideration in the course of the further development of the Hightech Strategy.

Although international comparative statistics seem to show that Germany is lagging behind in the provision of services, this could be a statistical artefact. We will return to this in one of our future reports and recommend that more research is carried out into innovative services in general.

Currently, the Hightech Strategy is clearly oriented towards technological developments which lead to improved R&D-intensive products. A strategic orientation towards the further development of innovative services is proposed. We urge that this is integrated in the Hightech Strategy.

The innovative products of the processing industries also involve services to an increasing extent, and in an age of global communications these contribute to the success of German exports. It is no longer possible to treat services as a residual sector of commercial activity, because they have key function for future productive activities and employment. There is considerable need for action here, because as far as we can see the Hightech Strategy has hardly addressed this development so far.

The mobilisation for targeted innovation processes by the Hightech Strategy is particularly difficult as far as services are concerned. Novel developments in the services sector have the character of process or organisational innovations and are characterised by relatively low technology intensity. In contrast, a considerable role is played by the acquisition of knowledge, which is hard to quantify, the 'absorption capacity', and the use of the existing stock of knowledge. Providing loans for innovative services is particularly difficult; these financing problems can act as a major constraint on the innovation dynamics of service providers. The intellectual property rights situation is complex and possibly represents a further constraint.

Focusing sustainability strategies

The Environment-Climate-Sustainability complex represents a crucial global problem field to which the German federal government attaches considerable importance. Within the Hightech Strategy, four of 17 innovation fields are directly related to this complex. It seems to us that the Hightech Strategy is still seeking its way here; it has not yet defined a coherent, inter-departmental strategy. In addition to the original formulation of the Hightech Strategy from 2006 and the progress report in 2007, there have been a range of other statements.[59] There is a need for consolidation.

Focusing solely on 'climate' would not lead to the desired goal. The German federal government quite rightly presents global climate change as a key problem faced by the world. But the avoidance of intolerable climate changes and the management of unavoidable ones have to be placed in the wider context of sustainability. We recommend that the Hightech Strategy should focus on 'Innovations for sustainable economic activity'. This would be close to the topic originally chosen in the Hightech Strategy 2006.

Priorities within the sector of innovations for sustainable economic activity

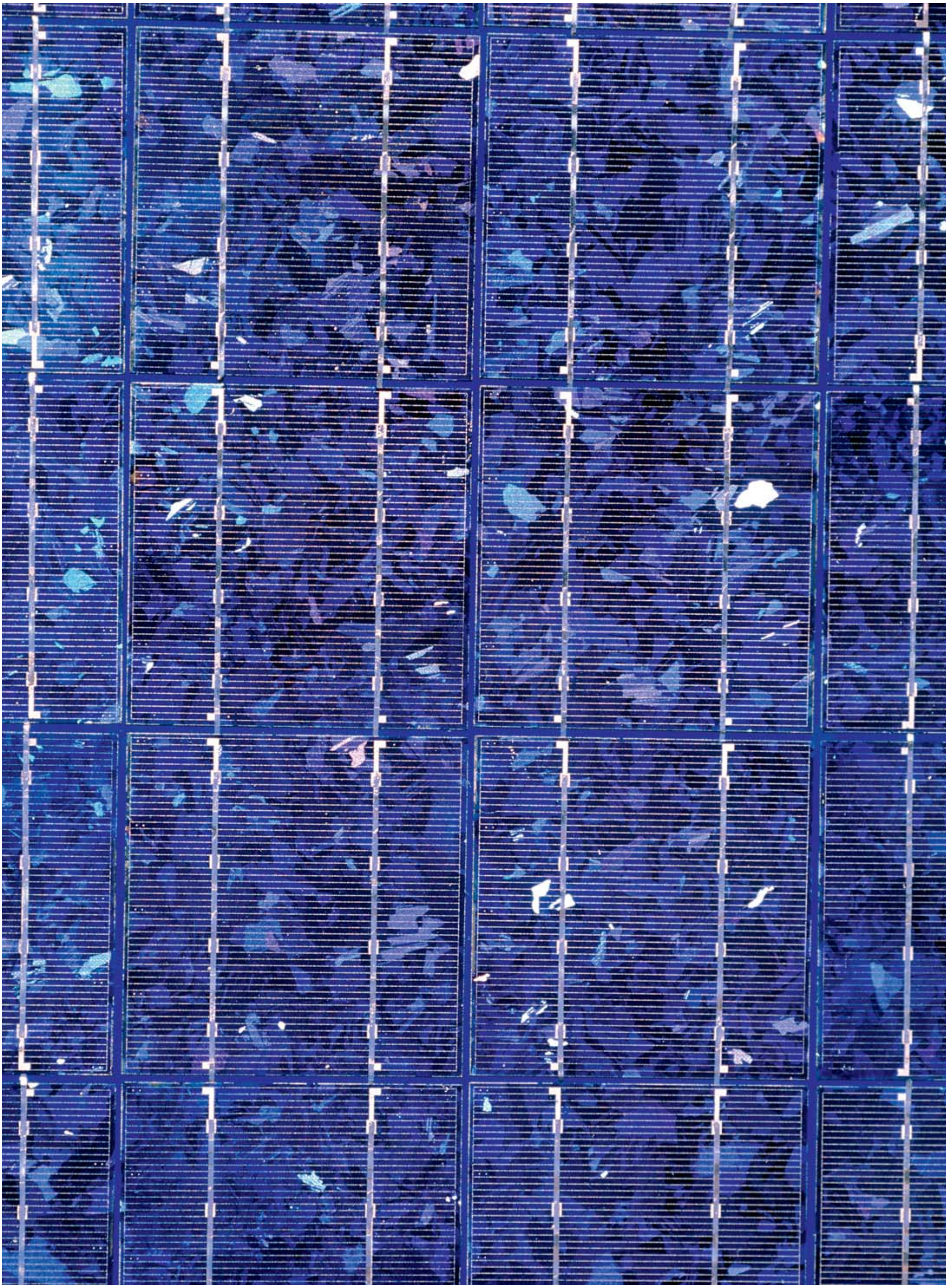
The proposed priority for the Hightech Strategy includes the climate as a topic, but from the point of view of the promotion of high-technology it is more comprehensive and probably also more effective. We propose that this sector should be sub-divided in the sub-sectors sustainable sources of energy, environmental technologies, sustainable production, and resource efficiency, as well as climate research. We feel that such structuring – which is fully in accordance with the Hightech Strategy – can lead to an increased goal orientation and can activate various synergies between the federal ministries. On the basis of its current strength in this sector, Germany also has excellent opportunities to develop relevant technologies and services for the global market.

Some examples of the technological opportunities in the four sub-sectors are provided in Table 02. German producers already have a strong position in these fields of technology on international markets and there is considerable potential for further innovations in these fields.

Most of these research and development topics were referred to in the original Hightech Strategy of 2006 at various places. We would like to make a comprehensive and focused proposal.

Goal-oriented strategies

Establishing priorities in the field of innovations for sustainable economic activity has the goal of ensuring the sustainable economic activity in industrialised countries, and also of promoting innovations for the maintenance and improvement of welfare in Germany.



Photovoltaic cells

Mangroves in the Ganges delta

The examples of innovative technological development given in the first progress report of the Hightech Strategy are impressive. The integration of the Research Union and the orientation to the topics of interests to business companies have contributed to the success of the Hightech Strategy. However, the emphasis is currently on relatively short-term commercial interests.

We think that it is important to establish 'Roadmaps' for the development of technology within the framework of the Hightech Strategy, with targets which would allow progress to be evaluated. Such roadmaps have proved their value for the coordination and control of innovation processes. We recognise that the extent of activated R&D expenditure is an important parameter for the success of the Hightech Strategy. With the aid of detailed roadmaps it would be possible to judge the success of the Hightech Strategy better, in particular in the long-term innovative fields.

Developing lead markets

A number German companies involved in generating power from renewable sources of energy (photovoltaics, wind energy) have been able to generate a lead market in Germany due to the market conditions provided there. A considerable contribution to the development of the technology has come from newly-founded enterprises. An important role in the development of the lead market was played by the Renewable Sources of Energy Act (EEG), which has created stable demand conditions in selected areas of technology. Of course this has also brought macroeconomic costs with it.[60] But to some extent Germany is currently technology leader in the fields of photovoltaics (solar cells) and wind power generation. There is a good chance that the Hightech Strategy will enable Germany to maintain or improve its position with regard to these products.

Improving the coordination of R&I responsibilities

Despite coordination, the responsibilities of two or more federal ministries can sometimes overlap, and they all find themselves involved in the supervision of aspects of the same field of technology. A certain level of political competition between individual departments may not be a bad thing. However, R&I policies are too fragmented in broad areas of energy research – in particular with regard to sustainable technologies. There is potential here for optimisation with respect to transparency, rapidity and efficiency.

TAB 02

Promising fields of technology for sustainable economic activity
Sustainable power supplies
Increasing efficiency in the generation, transports and use of energy
Using regenerative sources of energy, including biomass
CO_2-storage in fossil-fuel power stations and for fuels
Environmental technologies
Water and wastewater technologies, hydraulic engineering
Air purification
Sustainable agricultural technologies and settlement strategies
Sustainable production and resource efficiency
Material-cycle technologies, minimisation of waste materials
Production on the basis of life-cycle analyses
Reduction of the material inputs in production, substitution of scarce materials, use of regenerative raw materials
Optimisation of logistics
Energy efficiency in production
Climate research
Improving the local and temporal forecasting quality of climate models
Further improvement of the estimation of the consequences of climate changes
Development of technologies for controlling severe climate changes.

Quelle: EFI (2008).

The following federal ministries are involved in providing state aid for R&I in the field of energy technology: Federal Ministry of Education and Research (BMBF), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Federal Ministry of Economics and Technology (BMWi), Federal Ministry of Transport, Building and Urban Affairs (BMVBS), Federal Ministry of Food and Agriculture and Consumer Protection, (BMELV), Federal Ministry for Economic Cooperation and Development (BMZ), and Federal Ministry of Finance (BMF).[61] In view of the wide range of activities, some of which overlap, we propose that in the medium-term there should be an appropriate consolidation of responsibilities with the coordination entrusted to the research department.

Pursuing the Hightech Strategy – realising improvement potential

With the Hightech Strategy, the German federal government has adopted a promising new approach. The proposed coordination of federal government

BOX 11

Lead markets

Retrospective analysis of successful innovations, e.g. the video recorder, the fax machine or mobile communications, has shown that the scientific results were known long before a technology 'took off'.[62] It was only with the market breakthrough that local companies were able to obtain an advantage over foreign competitors in terms of experience with production and applications.

If two or more pioneers produce different technological variants of the same functionality, the one which is accepted first by a market, the lead market, establishes itself internationally and displaces alternative constructions in the 'Lag Markets'. The delay cannot be explained by lack of interest in innovation or opposition to technology. One country is not generally late or leading in the application of innovations. A whole series of factors all exert influences (legislation, cultural differences, the market power of good alternatives, regional entrepreneurial knowledge, marketing channels, availability of specialist personnel, etc.). It is therefore difficult to predict future lead markets in any individual case.

activities and the broad mobilisation in Germany represent important tasks and a successful start has been made. We have pointed out potential for further development: improved coordination with the *laender* and within the European Union, transparent information about future budget allocations, a plausible selection of the specific fields of innovation, and increase attention paid to services, and to sustainability innovations. The German government should continue to pursue this course energetically.

C 6 GROWTH POTENTIAL AND CUTTING-EDGE TECHNOLOGY

Innovation successes

Research and innovation are the foundation for the economic success of Germany. This is valid both over the longer-term, and recently for the economic upswing of 2006 and 2007, which was supported in particular by technology exports. Germany accounts for about a third of the world trade with R&D-intensive goods, and for many years has ranked second (relative to its population size) for globally relevant patents. Government and private expenditure on R&D is increasing again. At first sight the balance seems to be positive, but a more detailed analysis indicates structural problems.

Continuing weakness in cutting-edge technology

The analyses of R&D, foreign trade and patent activity in the EFI Innovation Studies show that the German innovation system has systematic weaknesses. Germany achieves its success in the area of high-level technology, but in an OECD comparison is only has a low ranking for cutting-edge technology. In particular the relatively mature sectors of chemistry, mechanical engineering and automotives account for the largest part of German R&D, patents, and exports.

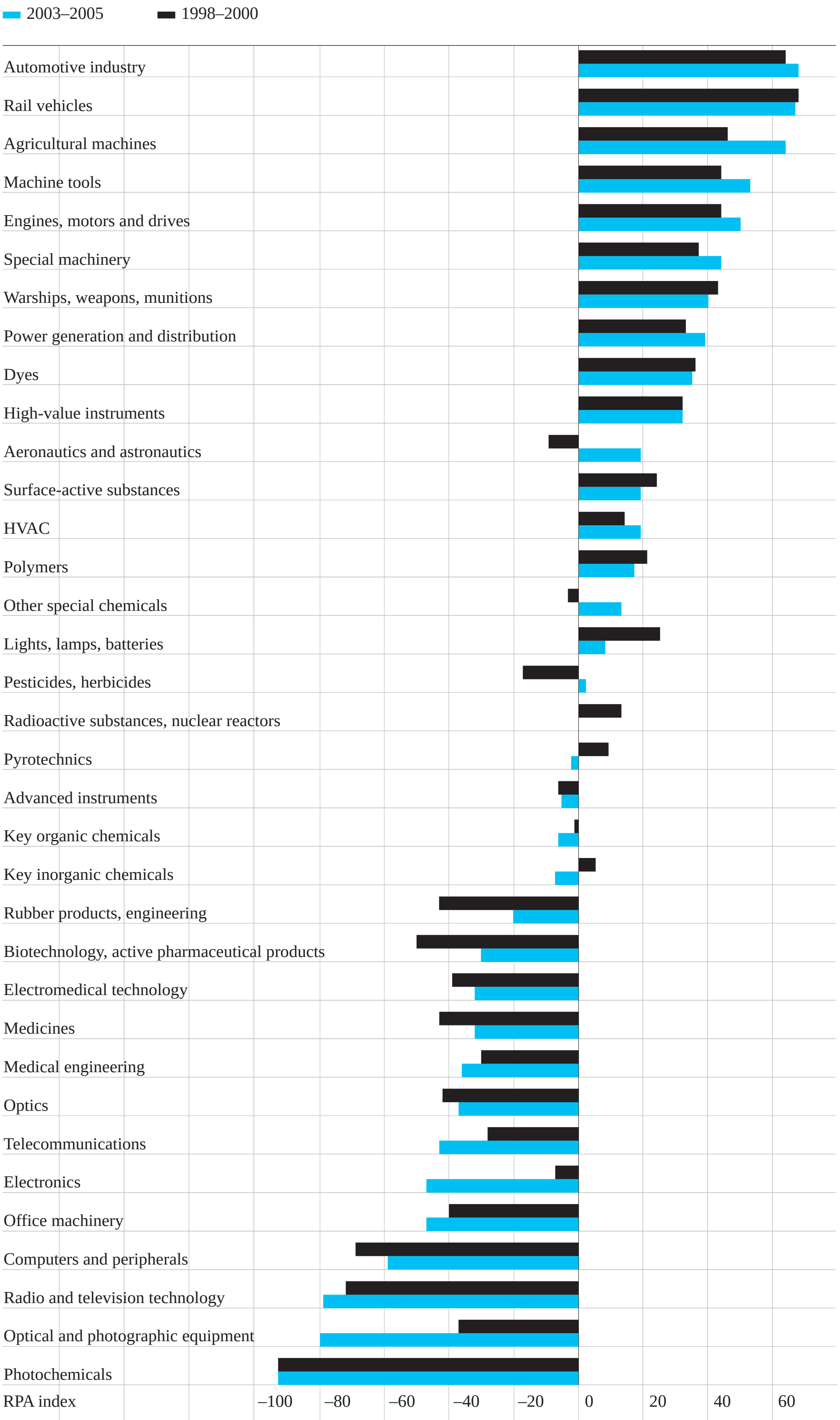
The R&D activities of German companies show marked patterns of specialisation which differ from those of other countries. For the OECD member countries overall, their R&D work has concentrated on cutting-edge technology, that is in areas in which the average R&D intensity is more than 7.5 per cent. For some years there has also been a clear shift in favour of R&D in the services sectors. At the start of the 1990s, about 30 per cent of all R&D capacities in the OECD were deployed in the less research-intensive sectors, including the so-called high-level technology. This proportion has meanwhile fallen to about 25 per cent. Germany diverges considerably from this trend, with a fairly constant level of more than 50 per cent of R&D capacity devoted to high-level technology. Put simply, while other countries are directing R&D capacities increasingly into services and cutting-edge technology in order to benefit from the above-average growth in these sectors, Germany continues to concentrate on high-level technology.

The focus of the R&D is reflected in a corresponding concentration of German patent applications in the field of high-level technology. There are disproportionate numbers of patents in the fields of chemistry, automotive construction, mechanical engineering, and electrical engineering.[64] Figure 5 shows that when it comes to internationally-oriented patent applications in cutting-edge technologies (e.g. computers, electronics, information and communications technology, pharmaceuticals) Germany's position is unfavourable.

It is also possible to demonstrate corresponding patterns of foreign trade specialisation. High-level technology products are exported most frequently from Germany, whereas the German imports are more dominated by raw materials and cutting-edge technology. Cutting-edge technology is only involved in about a quarter of the total exports of 428.3 billion

Germany's patent specialisation in high technology, 1998-2005

FIG 05



RPA (Relative Patent Advantage): A positive sign indicates that the field has a higher significance within the country in question than for the average of all countries.
Source: Frietsch (2008).

BOX 12

The chemical industry in Germany and Great Britain from 1840 to 1910[63]

The development of the chemical industry in the second half of the 19th century shows how rapidly a country can lose its technological advantage, and the importance of close cooperation between commerce and science (in this case the newly established discipline of chemistry).

Until 1840, the British chemical industry dominated the production of inorganic chemicals. Current main products such as ethylene, benzene, and propylene were unknown. About 1850, the idea arose that artificial dyes could be used in the textile industry. The discovery of the first synthetic dye, Mauve, by Perkins in 1856 catapulted the chemical industry into a new phase, and organic chemistry became the most important branch of the industry.

Perkins made his discovery in the laboratory of August Wilhelm Hoffmann, a German chemist who like others had moved to England because of the better working conditions and established himself as a leading organic chemist. British companies dominated the production of artificial dyes until the 1870s. All comparative advantages appeared to lie at this time on the side of the British chemical industry. Great Britain was affluent, its industry had the necessary expertise, could draw on major reserves of coal tar, and had the larges customer base, because artificial dyes were used primarily in the textile industry.

Yet within a few decades this comparative advantage had been lost or was no longer effective. By 1890 the German industry dominated organic chemistry. In 1913, German companies produced 140 000 tonnes of artificial dyes, Switzerland 10 000 tonnes, and Great Britain only 4 400 tonnes. America had become one of the largest producers of inorganic and some organic chemicals, but was dependent on German suppliers, who provided the dyes. Within three decades Britain had lost its leading role to the German chemical industry.

Which factors were significant for this development? In 1865, Hoffmann returned to Berlin and established leading research laboratory for organic chemistry. Soon research laboratories were introduced in the companies in the chemical industry. Companies and science managed to organise an intensive and mutually beneficial exchange of information. German universities trained chemists, who then researched in commercial laboratories to develop new organic compounds and to identify applications. Great Britain missed this development. The British banks were conservative, the elite universities of Cambridge and Oxford were sceptical of the 'useful' natural science of chemistry. In addition, the German patent system since 1877 provided incentives for inventions, and in contrast to France and Great Britain, the barriers to market entry were comparatively low.

euros in 2005. A large volume of exports, 328.6 billion euros, involved high-level technology.[65] Germany's trade balance is approximately in equilibrium for cutting-edge technology. The export successes were therefore achieved exclusively with high-level technology products.

The statistics give a consistent picture: R&D, inventions and innovations in Germany are mainly coming from relatively mature industries and in the field of high-level technology. With the products of these industries, German companies generate considerable foreign trade surpluses. But Germany has a weak position in the cutting-edge technology.

Advantages and dangers of focussing on high-level technology

Germany's specialisation in high-level technology has proved its value over a long period and has had numerous positive consequences. The export of high-level technology products currently secures jobs in Germany and generates welfare. The rapidly growing newly industrialising countries represent good markets in the medium-term for German high-level technology products. The specialisation can also create important efficiency advantages, with opportunities to organise financing, vocational training, and other institutional factors to suit the dominant sector of the economy.

However, Germany cannot rely on being able to maintain this specialisation advantage over the longer term. In particular the classic German sectors of chemistry, the automotive industry and mechanical engineering will lose importance over time as domestic employers. The wages of German employees are only adaptable within limits, and parts of the production are already being transferred to low-wage countries. The R&D activities of German companies will then either follow the production locations or be relocated to countries where the engineering and research work is less expensive. In addition to this, other countries are also catching up in the technologies in which Germany has so far been in a leading position.

Therefore, Germany will in future be dependent to a greater extent on accessing new value-creation potential, above all drawing on results from basic research. Germany was very successful in this respect in the case of the chemical industry in the late 19th century (Box 12). New technologies and resultant new industries can develop quickly. Nations without the requisite flexibility to react rapidly run the risk of losing touch with the developments. Germany has experienced this a number of times in the second half of the 20th century. Numerous developments in the fields of semiconductors, computers, and biotechnology were only noticed in Germany after some considerable delay. Despite good successes in basic research, the German innovation system has not mastered the step to the commercialisation of important inventions in these fields. The specialisation of Germany on high-level technology has thus been preserved, new industries with a strong position on the world market have only been based Germany in exceptional cases. Economically, Germany is therefore dependent on mature sectors in which the competition from newly industrialising countries and other competitors is becoming increasingly fierce. In order to release itself from this dependency in part, a new orientation towards cutting-edge technology is necessary.

Improve conditions for new industries

How can Germany continue to use and expand its established strengths while at the same time making provisions for the future and offering a fertile soil for new approaches? This question is faced by all other countries in Europe. We see two main options: Firstly, the creation of good conditions for starting up new companies with a high growth potential. Secondly, the R&I-support of the German government should in general be directed more towards cutting-edge technology.

A particularly important role in radically new forms of value creation is played by young, science-based companies.[66] Europe only makes use of this source of growth to a very limited extent. The Sapir Commission Report (2003) gives the example that in the USA more than half of all new drugs come from companies which are less than 10 years old – but in Europe only 10 per cent of all new active substances are produced by young companies. 12 per cent of the largest US-companies are less than 20 years old – against only 4 per cent of the largest companies in the EU. Europe in general offers poor conditions for the growth of new companies. And in Germany in particular no start-up dynamic has developed for 'Schumpeter goods', as has been prevalent in the USA since the 1960s.

German start-up weakness

The German weakness when it comes to starting up new enterprises is particularly striking. In this field Germany performs poorly across the board. The regular surveys within the framework of the Global Entrepreneurship Monitor (GEM)[67] show that new enterprises in Germany are comparatively rare. The climate for founding new enterprises still tends to be inhospitable.

Above all when it comes to start-ups in R&D-intensive industries and in knowledge-intensive services ('Schumpeter goods') Germany shows only weak activity. Figure 06 shows the percentages of companies starting up and closing down in the research-intensive industry and in knowledge-intensive services. In both cases, Germany is in the lower left quadrant, indicating an underdeveloped entrepreneurial dynamic.

Long-term risks

New enterprises represent an experiment for an economy, testing the viability of technologies and business models. Inventions and scientific findings may seem very promising, but without trying things out by starting up a new enterprise it is often not possible to make any reliable assessment of possible future successes. If there are few new start-up companies, then the risk is that new knowledge and new technologies in Germany will not be adequately commercialised very often. Even if German research institutes and universities carry out successful research, the results will only generate value locally if it is also possible to transfer them to applications in Germany. Of course inventions can be licensed. For example, the licenses taken out by the team of the Nuremberg research Karlheinz Brandenburg relating to the MP3 standard have provided the Fraunhofer Gesellschaft with a very welcome flow of revenue. But the first devices using the standard were developed in Silicon Valley, not in Germany. And compared with the value creation in other countries the license fees are relatively small.

Causes for the poor start-up record

There are various reasons for the poor start-up record in Germany, and it is also influenced by the long-standing underdevelopment of an entrepreneurial culture. The situation regarding financing and taxation, and a wide range of bureaucratic obstacles to starting up new enterprises also contribute considerably to an unfavourable situation. The removal of constraints to innovation in the tax system, in particular relating to carrying forward losses and the approach to venture capital financing, could increase the incentives to start up new companies and would help to make the German innovation system more flexible and dynamic. Such incentives would also generate in influx of private capital and reduce the current dominance of state financing in the early phase of setting up new enterprises.

BOX 13

Results of the Global Entrepreneurship Monitor (GEM) 2006

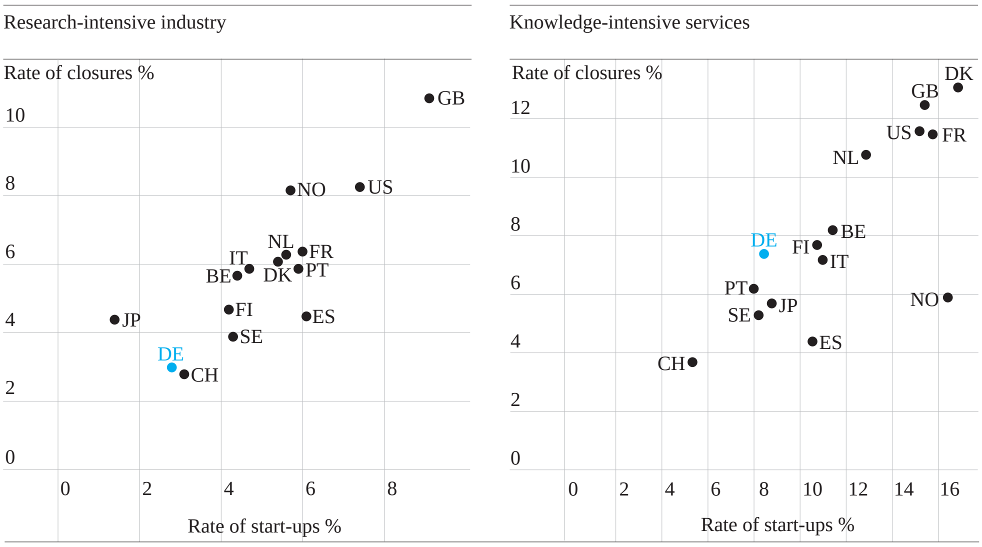
The Global Entrepreneurship Monitor (GEM) is a long-term project supported by a consortium of international research institutes to monitor entrepreneurial activities, with standardised surveys of frequencies of start-ups, entrepreneurial motivation and other parameters in 42 countries.

The results of the survey in 2006 again show a very low entrepreneurial motivation in Germany. Only 2.9 per cent of 18- to 64-year-olds had tried to start up their own business, putting Germany in 34th position. Of the German new entrepreneurs a relatively high percentage felt obliged to choose self-employment, in contrast to the opportunity-orientation common in other countries such as the USA and Great Britain. The low involvement of women in entrepreneurship is also striking.

Out of 37 countries, Germany ranked 16th for entrepreneurial activity and 13th for new enterprises with medium or high technology intensity. Respondents criticised the following factors in Germany: poor support for self-employed by social values and standards (34th out of 37), poor link to entrepreneurship in school education / vocational training (31st / 35th out of 37), poor support for women starting up in business (36/37). The big strengths of Germany were the physical infrastructure, the protection of intellectual property, and state subsidies.

Start-ups and closures in selected countries[68]

FIG 06



Not including banks and insurance companies. Data for 2004 or the nearest available year.
Source: Eurostat, US SBA, UK SBS, INSEE, Statistical Office of Japan, ZEW. Calculations by ZEW.

Making it easier to start up in business

In comparison with other European countries, German legislation does not make it easy for entrepreneurs to set up a new company. This is particularly the case when the founders want to limit their personal liability. The costs for setting up a 'GmbH' are comparatively high, and the process takes longer than in other countries.

When setting up knowledge-intensive companies in Germany, the 'GmbH' is often appropriate, but it faces competition in the European Union from other options.[69] The boom in new enterprises starting up in Germany as 'limited companies' has led the legislators to propose the reform of the GmbH-legislation. In particular the level of capital required to set up a 'GmbH' is to be lowered. At the same time, however, the liability regulations are to be made tighter. The proposal has led to a controversial discussion.

The German federal government should ensure that the reform of the GmbH Act is considerate of the needs of young entrepreneurs. It must be possible to set up a limited liability business quickly and without excessive costs. A goal should be to offer online business registration, which is already available in Great Britain and is planned in other European countries. European competition for new enterprises is now underway. The success of the government reforms will decide whether Germany is successful in the competition for innovative activities. Germany must develop from being the country of new ideas to the country of new enterprises, in order to be successful as a location for innovation in the long term.

Policy measures – First successes and the need for further action

Financing new enterprises must be made easier, and a long term improvement is needed in the conditions for then nurturing their growth. The German federal government has already taken steps in the right direction with numerous initiatives. The Hightech Start-up Fund is an important institution for the early phases of financing high-technology companies. It invests risk capital in young technology companies aiming to commercialise promising research results. Seed financing of 500 000 euros can be provided for the companies. The

High-Tech Start-up Fund has some 270 million euros available. Most of the funds come from private sources.

Independent research institutions and universities are also intensifying the transfer of technology. Since February 2002 inventors at universities are no longer 'free inventors' within the scope of the former Employee Inventors Act, and now the university has the right to decide about the exploitation of intellectual property. Technology transfer is a duty of the universities, and a challenge which many of them have been slow to respond to. Currently, technology transfer is often troublesome and is regarded by many researchers as unnecessarily bureaucratic. Businesses and scientific institutions have the responsibility to improve their cooperation and the transfer of knowledge from research to application.

Other developments also give grounds for optimism. German universities have set up some 70 chairs in the field of new enterprises and entrepreneurship. Students are no longer only trained for careers in large and medium-sized companies but are also prepared to start up their own company or work in a new enterprise.

The 'Exist' Programme of the Federal Ministry of Economics and Technology and the associated 'Exist' measures to provide seed funding, start-up grants, and research transfer help are intended to stimulate spin-offs from universities or research institutions. New enterprises are also supported by the GO Bio Programme of the BMBF. Research teams from the field of biotechnology wanting to start up in business in the next decade can draw on a total of 150 million euros of state aid. The working groups will be expected to develop new methods in the life sciences, develop potential applications and prepare the commercialisation. The explicit goal of this form of promotion is the establishment of biotechnology companies. It is not yet possible to make a final assessment of how successful these measures will prove, but the overall goal is right: increased support for young companies and improved commercialisation of research results.

However, these successes may be thwarted by the poor social esteem in which entrepreneurs are held, the disadvantages imposed on innovations in the tax system, and bureaucratic constraints. State aid and financing only have a limited range, and it is very important to create incentives for private investors in order to provide the new enterprises with more growth opportunities. Further efforts are also necessary to make Germany an attractive location for new enterprises.

Taking more risks, providing more aid for cutting-edge technology

Germany has so far been successful with its specialisation in incremental innovations. But this cannot go on indefinitely. Innovation policies are also an element of risk management

BOX 14

Technology transfer

Researchers and implementers do not have to work in the same organisation. Often research results originate outside the innovating companies, e. g. in universities or research institutions. Discoveries and technical information then has to be transferred, which in some cases necessarily involves the original researcher and inventor, for example in a new enterprise.

If knowledge and technical information are linked to individuals, then innovations can have specific local effects for value creation. There are macroeconomic benefits because value is created at the place where the knowledge is generated. This can lead to the formation of clusters and in the longer term to regional agglomerations in which knowledge, capital and specialist are all readily available.

BOX 15

Resistance to innovation

Not everybody has an interest in the success of an innovation. The process of creative destruction means that there will be losers as well as winners. Resistance to innovation can also be motivated by fears or cultural prejudices and may express itself at various levels – in the society, between competitors, or at the level of individuals.

Resistance is likely to be stronger the more radical an innovation is. For a radical innovation, a company will probably have to implement completely new technologies or forms of organisation at considerable cost.[70] In the case of completely new technologies and business strategies the innovators will initially have to convince financiers, customers, suppliers, employees and many others. In 1980 it was much more difficult than today to find financial support (venture capital) to start up biotechnology companies.

Incremental innovations, on the other hand, can often be introduced while preserving many parameters of the technology or organisation, so that there is less resistance – there are hardly any innovation losers. Incremental innovations often follow on from a radical innovation, because the diffusion of an innovation often leads to quality improvements, learning effects, and stepwise adaptations.

Resistance to the introduction of innovations is often encountered within a company.[71] Employees can lose their jobs if new machines are introduced (process innovation). Industrial robots in the 1980s became symbols of the fear of unemployment due to process innovation and rationalisation. These are known as the Liabilities of Newness.[72]

for Germany. New enterprises, particularly in cutting-edge technology, are an important way of testing and identifying new potential for value creation. The German federal government should take decisive steps to remove the constraints encountered by new enterprises, in particular regarding financing and taxes. A number of measures have already been adopted with regard to other problems, such as the high costs of setting up a business and inadequacies in entrepreneurial training in the university sector. Further progress must be made along this path. We already see positive signs for a new orientation.

The implementation of new knowledge and new ideas in commercially viable products is of vital importance if Germany is to remain internationally competitive. The German federal government should attach increasing importance to the conditions for radical innovations. Obstacles to such innovations should be removed to make it easier for the industries of the future to develop. Support should go primarily to cutting-edge technology, in order to open up long-term growth potential in Germany.

D

D DETAILED REPORT ON RESEARCH AND INNOVATION IN GERMANY

D 1 CURRENT ECONOMIC STRUCTURES

In this section we examine data from the fields of production, foreign trade, and employment particularly with regard to research-intensive and knowledge-intensive sectors.[73]

Strong trend towards a knowledge-intensive economy

Between 1995 and 2007 the gross domestic product of Germany increased by some 20 per cent in real terms, in the EU-15 member countries by 30 per cent, and in the USA by almost 45 per cent. In Japan the growth was lower at about 15 per cent. After a stagnation phase between 2001 and 2003, Germany belatedly resumed a path of growth and from 2005 once again showed stronger growth. But despite this improved dynamic it has not been able to catch up again after falling behind over the past ten years.

These values conceal very different structures for research- and knowledge-intensive sectors and the rest of the economy. The contribution of the research- und knowledge-intensive section of the economy to total value added in Germany increased between 1995 and 2005 from 40 to 46 per cent – indicating a clear structural change in favour of this sector.

Value added in the research-intensive industries

In the Manufacturing, the increase in value added and the growth in employment are attributable mainly to research-intensive sectors; more than 80 per cent of the growth in industrial production since the mid-1990s comes from the research-intensive sectors. The expansion in the 1990s resulted primarily from the stable growth of the automotive manufacturers and suppliers, from the chemical industry, and from mechanical engineering. The year 2000 marked a turning point in the economic development. Until 2003 the production in the R&D-intensive industries grew on average by only one per cent per annum, but since 2004 they have profited from a growing demand both internationally and domestically. The production in research-intensive industries increased annually from 2003 to 2006 by 6.3 per cent on average. The other industries only achieved an annual increase of 2.5 per cent. This accelerated the increasing orientation of German industrial production towards research-intensive products. R&D-intensive industries accounted for some 53 per cent of industrial production in 2006 (Figure 07).

In the current upswing there has been an annual average growth of production in the cutting-edge technology section of research-intensive industry of 11.5 per cent from 2003 to 2006. This is primarily attributable to ICT technologies – once again the most dynamic sector with annual growth rates of 20 to 30 per cent. High-level technology also showed considerable increase in production between 2003 and 2006, particularly in mechanical engineering. Thus there is a structural change towards the cutting-edge technologies, however the contribution to value added in 2005 was only three per cent compared with twelve per cent for high-level technology. Thus in the medium-term there will only be a slow change of the current weights between high-level technology and cutting-edge technology.

Strong links between research-intensive industry and knowledge-intensive services

The growth in production in Germany has not in fact led to the creation of additional jobs. On the contrary, between 1995 and 2006 employment in research-intensive industry fell by twelve per cent. However in the rest of industry it fell by 18 per cent, so that the research-intensive sectors have prevented an even greater overall decline in industrial employment (Figure 03).

Research-intensive industries have concentrated more on their core-competence, namely making end-products. They have developed horizontal production structure and have out-sourced pre-production to non-research-intensive industries, the services sector, and to other countries. Between 1995 and 2000 the value added in the research-intensive industries sank annually by 3.7 per cent. The result was a reduction in jobs in the research-intensive industries.

The knowledge-intensive services have shown particularly high rates of growth. Between 1995 and 2005 their share of value added increased from 27 to 31 per cent. In 2006, know-ledge-intensive services employed almost 41 per cent of the personnel working full-time in the business services economy and of almost 25 per cent of those in the total commer-cial economy. The expansion of services is above all attributable to outsourcing and pre-performance cooperation between industrial companies and service providers. Their demand for high-value pre-products and equipment means that service providers are increasingly becoming a driving force in innovation processes. As in other industrialised countries, the German economy is going through a double structural change:

– The growth in the industrial sectors is moderate in comparison with the services sector – the employment balance since the start of the 1990s has been clearly negative.
– Knowledge-intensive and research-intensive sectors of the economy are expanding in both in the manufacturing and services sectors.

Growing contribution to employment by knowledge-intensive services

In contrast to manufacturing industry, the services have made a positive contribution to employment in Germany since the mid-1990s, more so in the case of the knowledge-intensive services than other services (Figure 03). In the knowledge-intensive services, the number of hours worked between 1995 and 2006 rose by 22 per cent, and in the other services by three per cent. Similar tendencies can be observed internationally. Employment in the in-dustrial sector is declining in most developed economies, although to a lesser degree in the research-intensive industries than in the non-R&D intensive ones. In contrast, in the know-ledge-intensive services sector there has been a broad increase in hours worked everywhere, although in Germany there was a period of stagnation in the development of employment at the start of this decade.

German weakness in labour productivity

Labour productivity is an important indicator, and in Germany in 2005 it was 18 per cent higher for the business economy than in 1995. However a long-term comparison shows a noticeable weakening in productivity growth. Within the economy as a whole, the R&D-intensive industries show growth of some 45 per cent, considerably above the average. But over the same period R&D-intensive industries in the USA achieved a growth in produc-tivity of 150 per cent, and the EU-15 of 120 per cent. Compared with the USA, Germany lagged behind on average by 5.5 per cent per annum. Productivity in the knowledge-intensive services in Germany grew between 1995 and 2005 by eight per cent, which is much lower than in the manufacturing industry, although this corresponds to the usual structures for the services. Germany again does not do well in an international comparison. Labour productivity increased in this period in the USA by 28 per cent and in EU-15 by 21 per cent.

Regarding the components of productivity growth, a comparison between Germany and the EU-15, the USA, and Japan shows that the hours worked in manufacturing industry is declining in each case, whereas there is an increase in the hours worked in the knowledge-intensive services. The use of ICT capital goods is particularly important for the increase in labour productivity in the knowledge-intensive services, and here too Germany lags behind its competitors. The high level of growth in the research-intensive industries is based primarily on the improved properties of technical products. Here Germany is much worse than the USA and Japan. In addition, in the United States the increased use of ICT capital also plays a significant role in the manufacturing industry. The combination of both factors explains the lead role of the USA in the development of labour productivity.

In all, Germany has improved the presence of research-intensive goods and knowledge-intensive services in its economic portfolio. Measured in terms of hours worked and valued added, the economic structure of Germany stands up well to international comparisons, with the most important factor being the high-level technology. This has been possible despite the fact that the period from 1995 to 2005 was one of weak growth in the German economy: sectors which were less knowledge-intensive had no growth opportunities in this period. At the same time, productivity development increasingly lagged behind that of important competitors. This was the case for all sectors, but in particular also for research-intensive industries and knowledge-intensive services. Germany does not have a direct structural problem, but does have a serious problem of dynamics.

Germany top for the proportion of value added by the knowledge-intensive sector of its economy in international comparison

In a recent comparison of the contribution of the knowledge-intensive sector of the economy to total value added, Germany came out ahead of the USA, the EU-15, the EU-10, and Japan. It has meanwhile even overtaken the USA, which in 1995 still held a considerable lead. This is due above all to the value added by high-level technology. The contribution of the knowledge-intensive services has also increased considerably over the past decade. The 31 per cent of value added in 2005 is well above that of EU-15, but still less than that of the USA, which was about 36 per cent (Figure 08).

German specialisation in high-level technology

An international comparison highlights Germany's strong and growing specialisation in research-intensive industries and in particular in high-level technology. Germany has meanwhile reached an average value for cutting-edge technology products. In the comparison of EU-15, USA, Japan, and Germany, only Japan currently shows marked specialisation here, with its strengths in the computer industry and in media technology. Germany's cutting-edge technology is focused on measurement technology, medical engineering, and pharmaceutical products.[74] Only the USA shows above-average specialisation in the knowledge-intensive services, with Germany at least reaching an average value in this case.

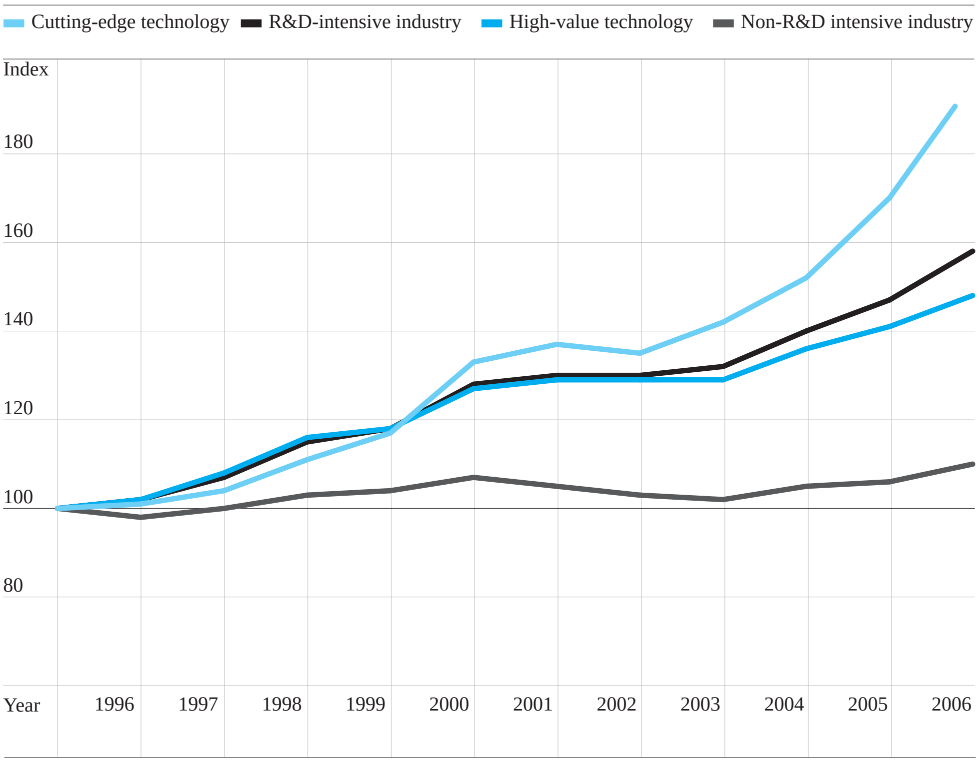
Export successes with high-level technology

The production sector in Germany relies heavily on exporting its products. With an export ratio of about 38 per cent in 2006, Germany was well ahead of all other large industrialised countries. Only smaller countries such as the Netherlands, Austria, or Sweden have higher export ratios. At the same time, the German import ratio of about 31 per cent is also comparatively high. In 2005, research-intensive products accounted for some 56 per cent of exports and 51 per cent of imports of OECD countries. These figures have declined since the year 2000, but are still considerably above those in 1993.

In foreign trade there was a decline above all in cutting-edge technology products, whereas high-level technology products increased further in significance. The decline in trade with cutting-edge technology products can be attributed above all to the end of the New-Economy boom in 2001, which was strongly influenced by ICT products. The proportional decline of cutting-edge technology is also due to the changes in prices in relation to non-R&D-intensive products, because processed goods with low technology content have become noticeably more expensive since the year 2000 due to the rising costs of raw materials.

Net production in R&D-intensive industrial sectors in Germany

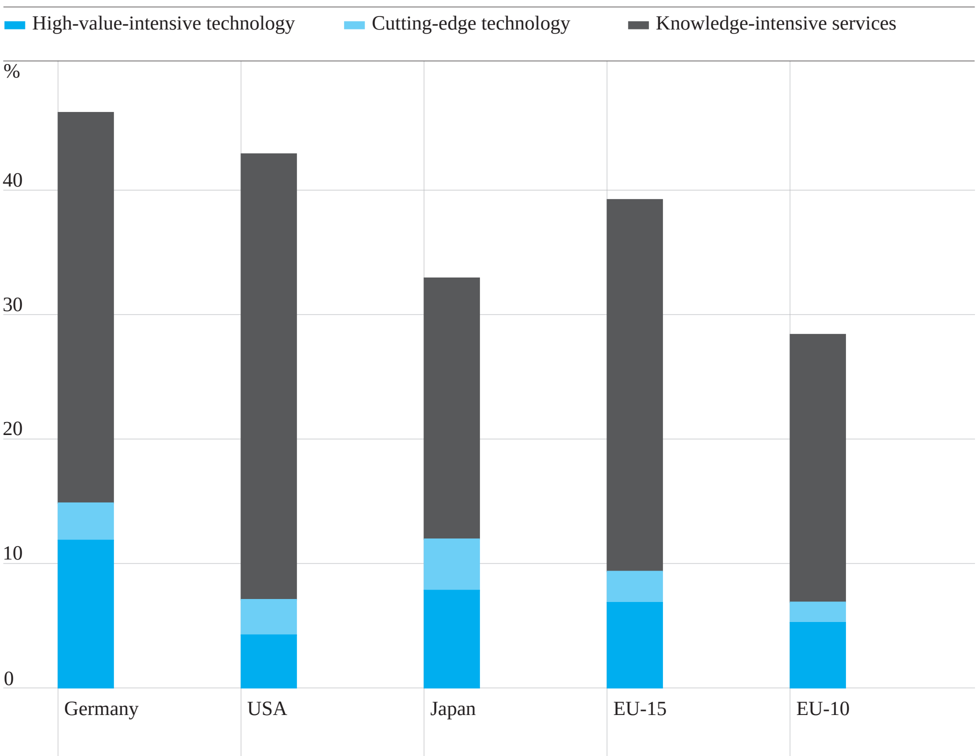
FIG 07



Index 1995 = 100.
Source: Statistisches Bundesamt, Calculations by NIW.

Contribution of R&D-intensive industries and knowledge-intensive services to total value added in 2005

FIG 08



Source: EUKLEMS Database 11/2007. Calculations and estimates by DIW.

German foreign trade with R&D-intensive products has grown considerably faster than trade with other processed industrial goods, and this applies equally for imports and exports. In cutting-edge technology, medical equipment and measuring technology products are the most important exports, whereas computer equipment and medical and measuring technology are in the lead among the imports. Foreign trade with high-level technology is dominated by the automotive industry, which accounts for more than half of the exports and imports. Mechanical engineering products are a considerable way behind in second place, and then again some distance behind follow chemical and electrical engineering products.

Shrinking advantage in foreign trade

» D 2 Looking at the foreign trade balance, Germany is showing a deficit regarding cutting-edge technology products, but a surplus with high-level technology products. These structures are usually analysed in terms of the Revealed Comparative Advantage (RCA) index.[75] A positive value of this index is interpreted as a showing of a foreign trade position for a specific group of a country's products which is stronger than its overall economic position. Since the beginning of the 1990s, there has been a gradual decline in the values of this RCA index for Germany, because imports have increased more rapidly than exports. For cutting-edge technology products, the values are clearly negative (Figure 09), whereas for high-level technology the index is positive. Overall, the foreign trade position in high technology is slightly above average, although showing a downward trend.

The influence of various categories of products on Germany's competitive position is demonstrated by their relative contribution to the balance of trade. A comparison over the past decade shows that the figures for R&D intensive goods have declined markedly from 3.8 in 1996 to 1.5 in 2006 (Figure 10). For cutting-edge technology goods the figures are even more negative, and for high-level technology the positive value has fallen. However, the overall profile of specialisation has hardly changed. Significant positive contributions are provided by automotive manufacturing and mechanical engineering. The values are negative for telecommunications, office machinery, and computer equipment. There has been a reversal from positive to negative in the cases of chemicals and pharmaceutical products. In all, the strengths and weaknesses in foreign trade are a reflection of the production situation.

It is more difficult to judge Germany's position in foreign trade with knowledge-intensive services due to the shortage of good data, and various special factors. The balance of payments has improved between 1999 and 2006 for all knowledge-intensive services. However, direct exports only cover a small part of the trade in these services. They can frequently only be sold through local subsidiaries, because the performances require direct contacts with the customers. Almost all knowledge-intensive services generate a large proportion of their turnover through their foreign subsidiaries, and this business has been growing more rapidly in recent years.

RESEARCH AND DEVELOPMENT

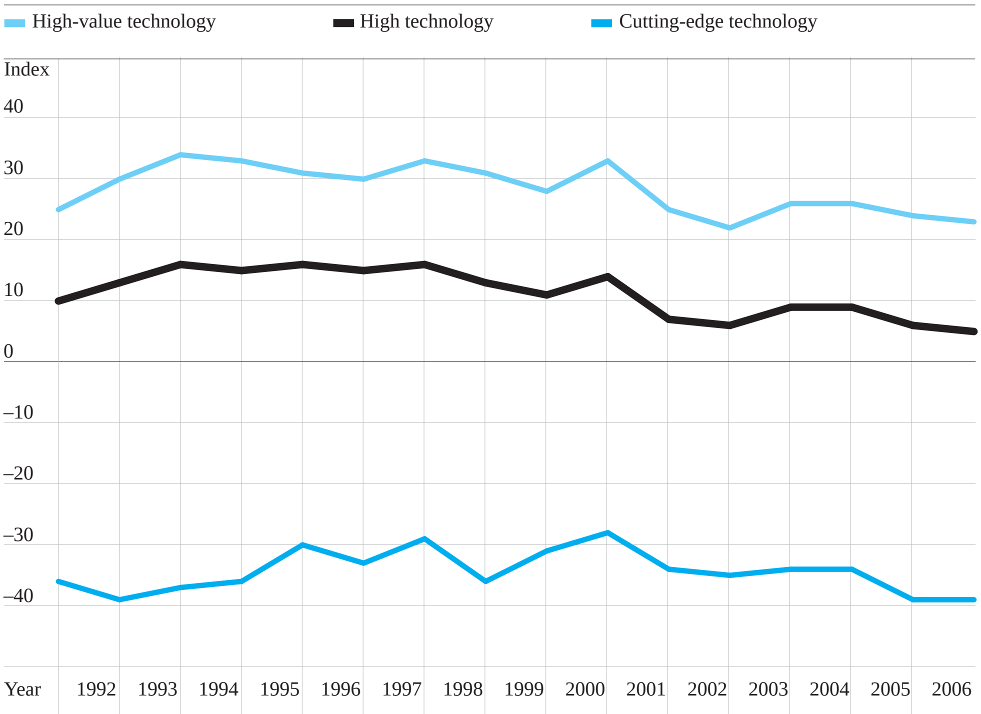
Research and development (R&D) in business, universities und scientific institutions plays a central role in the chain of education and qualification, science, research and technology, inventions, investments and innovations, productivity, international competitiveness, growth and employment.[76] All empirical studies show a generally positive influence of R&D on macroeconomic parameters. In addition, however, there are a series of other influential factors, complex interactions and a variety of pre-conditions. In short, R&D in highly developed economies is necessary but not sufficient for innovation processes. Given the importance of research-intensive industries and knowledge-intensive services for production, the generation of employment, and foreign trade, R&D is a key element for the development of the technological potential of Germany.

In-house research and development increasingly important for companies

More innovators in Germany are carrying out their own R&D. In 2006, two-thirds of industrial innovators carried out their own R&D, whereas in 1998 it had been a half. Germany has a good position for R&D in an international comparison. In the 1980s it was one of the leading industrialised countries – in a phase in which R&D capacities was expanding very rapidly worldwide. This had been the result of an enormous intensification of R&D in Germany in almost all branches of industry, together with a transformation of the industrial structure and a shift

Revealed Comparative Advantage (RCA index) of Germany in foreign trade with R&D-intensive products

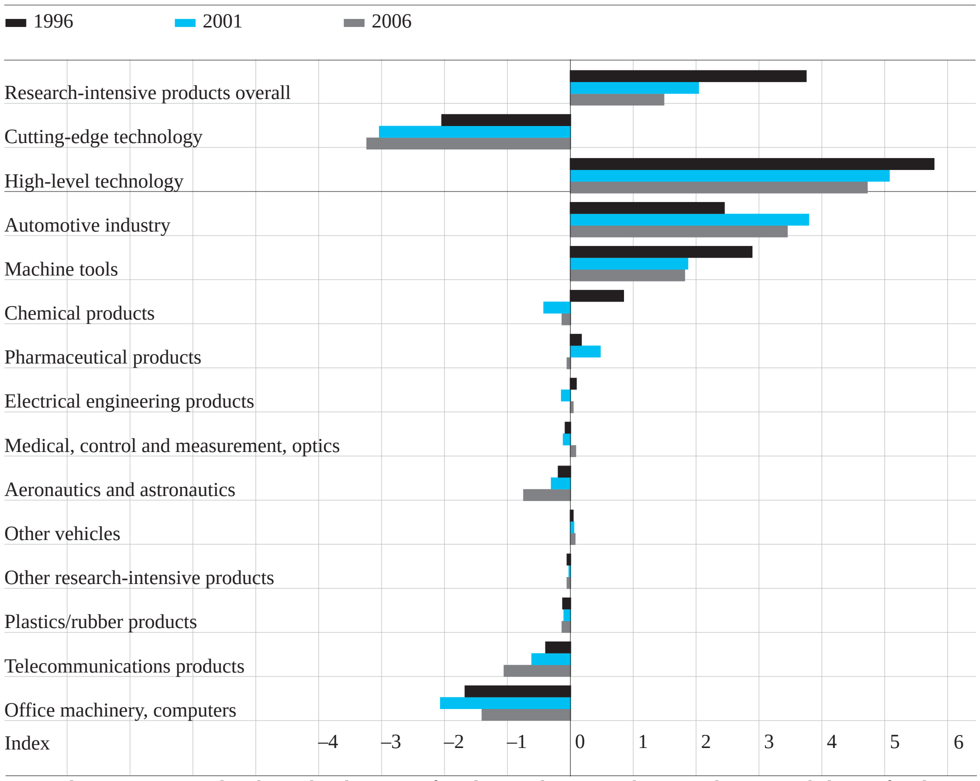
FIG 09



RCA index: A positive value means that the export-import relation for Germany in this technology group is higher than this relation for all processed industrial products.
Source: UN. Calculations by RWI.

Contributions of R&D-intensive goods to the German balance of trade

FIG 10



BAS index:[77] A positive value shows that the group of products makes a contribution to the German balance of trade which is above the average for all manufacturing industries.
Source: UNO. Calculations by RWI.

towards research-intensive manufacturing sectors. This dynamic came to a standstill in the early 1990s, and the R&D intensity in Germany had fallen markedly by the mid-1990s.

In the second half of the 1990s there was a rise worldwide in R&D intensities, followed again by a stagnation of development. The changes in the current decade have affected in particular the USA, which experienced a considerable drop in R&D between 2000 and 2002. This meant that Germany had now almost reached the American R&D intensity (Figure 11). However, this has not been due to an increase in its own efforts, with the exception of the recent increase in the macroeconomic R&D intensity in 2006.

Of the countries compared, the steady relative growth of R&D expenditure by Japan since the mid-1990s is remarkable. In the 1990s, Finland and Sweden started a massive increase in R&D activities, although this was slowed down by the end of the New-Economy boom in 2001 (in particular in Sweden). Both countries are still in the lead with R&D intensities in 2005 of 3.8 per cent and 3.4 per cent, respectively. Among the smaller countries, Switzerland and Korea have high R&D intensities, with three per cent in 2005.

Three-percent goal still a long way off

The EU-15 countries in all still only spend 1.9 per cent of their domestic products on R&D. This has not improved since the start of the 1990s, and they continue to lag behind the USA and Japan. The European Union is far from the three percent goal it has set itself for 2010. Whereas Germany at the start of the 1990s still held a leading position for R&D intensity, it is currently only in the upper-middle ranks. Some years ago it regarded the USA and Japan as the measure for international technology competition, but now reference is often made to the much lower average value for the EU-15. It would seem that with a view to international competitiveness a reference to the OECD member countries would be more appropriate. Despite a relative improvement since the mid-1990s, the advantage of Germany with regard to R&D intensity has been considerably reduced over the long term. Many OECD member countries have continually increased their efforts in this sector in recent years. And the technology competition with newly industrialised countries has also become considerably more intense.[78] With a macroeconomic R&D intensity of about 2.5 per cent, Germany will not be well-placed in the long term for technology competition.

Although production development in Germany has been undergoing a restructuring process towards more cutting-edge technology, it has not quite reached international rates of growth. The German cutting-edge technology now stands up well to an international comparison of specific R&D intensity – with the exceptions of the information and communications sector and pharmaceuticals.

In the worldwide transformation of R&D structures, there has been a marked decline in high-level technology, in which Germany has traditionally been strong. A positive exception is the automotive industry, in which there was a marked increase in R&D in the 1990s. This has been primarily responsible for the fact that over the past decade the level of R&D activity of the German economy has remained at a high level. Germany's share of R&D in the automotive industry among the most important industrialised countries has thus increased over the long term from 10 to 25 per cent.

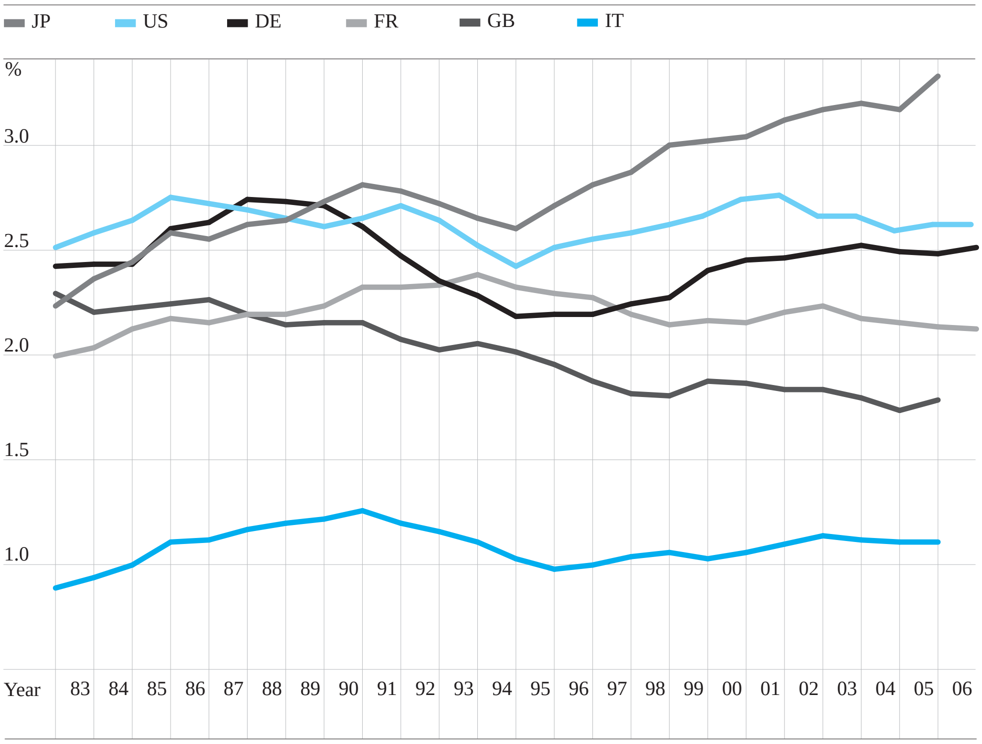
Rising R&D intensity in pharmaceuticals and the automotive industry

Rankings of industries according to R&D intensity are very similar for most countries. There have been some slight changes in Germany over the past decade. Structural changes have seen aeronautics/ astronautics, electronics/ telecommunications and computer/office machines overtaking by the pharmaceutical industry, and also by instrument construction and the automotive industry (Figure 12). In a series of industries increases in R&D expenditure have often not kept pace with the growth in turnover, which has led to declining R&D intensities.

Knowledge-intensive services are growing in importance both in terms of value added and also as a motor for innovation. They contribute above all as users to the diffusion of innovative technologies, and also define new demands on technologies, which in turn has an effect on the R&D of companies. High-value service providers are in contact in particular with those sectors of industry which carry out advanced R&D. For reasons of efficiency, there has been a growing division of labour between manufacturers and the specialised R&D, planning and engineering service providers. In

Proportion of GDP spent on R&D by selected OECD member countries

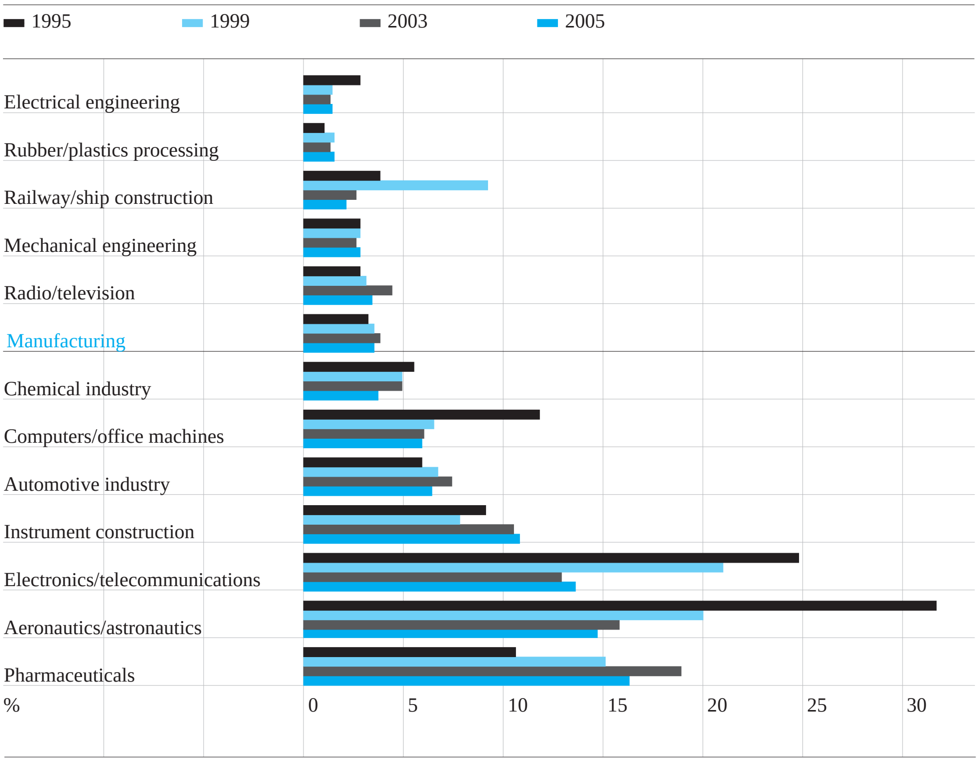
FIG 11



Data estimated in part.
R&D expenditure slightly overestimated in Japan until 1995. Until 1990: West Germany.
Source: OECD, Main Science and Technology Indicators (2007/2). Calculations and estimates of NIW.

R&D expenditure relative to turnover for selected sectors

FIG 12



Source: SV-Wissenschaftsstatistik, StaBuA, FS 4, 4.1.1 and 4.3. Calculations by NIW.

Germany, businesses are attaching more and more importance to research and development for high-level services.

R&D is often hard to identify in services companies, because the available statistical instruments are oriented towards innovation activities in the manufacturing industries. Innovations in the services sector are much less dependent on R&D than in manufacturing industry, but despite the statistical difficulties, the data clearly shows a structural change. Whereas at the start of the 1980s only one per cent of R&D personnel were working in the services sector, this had increased by the early 1990s to three per cent, and is currently at eleven per cent. Nevertheless, Germany is still far behind in an international comparison.

Current R&D expenditure declining in manufacturing industry, rising in services sector

In 2005 R&D personnel increased by 1.5 per cent, above all in the services sector and in SMEs. Manufacturing industries reported a reduction of internal R&D activities (down 1.2 per cent). In particular large manufacturing companies cut back on R&D personnel and reduced expenditure on R&D. SMEs providing business-related services, on the other hand, have recruited more R&D personnel. This is a reflection of an increase in R&D outsourcing.

The decline in internal R&D expenditure is concentrated in the automotive industry, ICT, electrical engineering, media technology, measurement and control technology, and the chemical industry. In contrast, there have been increases in the pharmaceutical industry and the mechanical engineering.

Short-term demand developments determine R&D activities

Ideally, R&D activities would be anti-cyclical, with developments during periods of economic stagnation preparing for phases of dynamic growth. But since the start of the 1990s it has been possible to observe an increasing pro-cyclical link between economic cycles and R&D activities. However, even the economic upswing since 2005 initially showed no signs (until 2006) of having been used for above-average investments in the development of new technical knowledge. R&D is increasingly oriented towards short-term changes in demand and the prospects of growth in the near future.

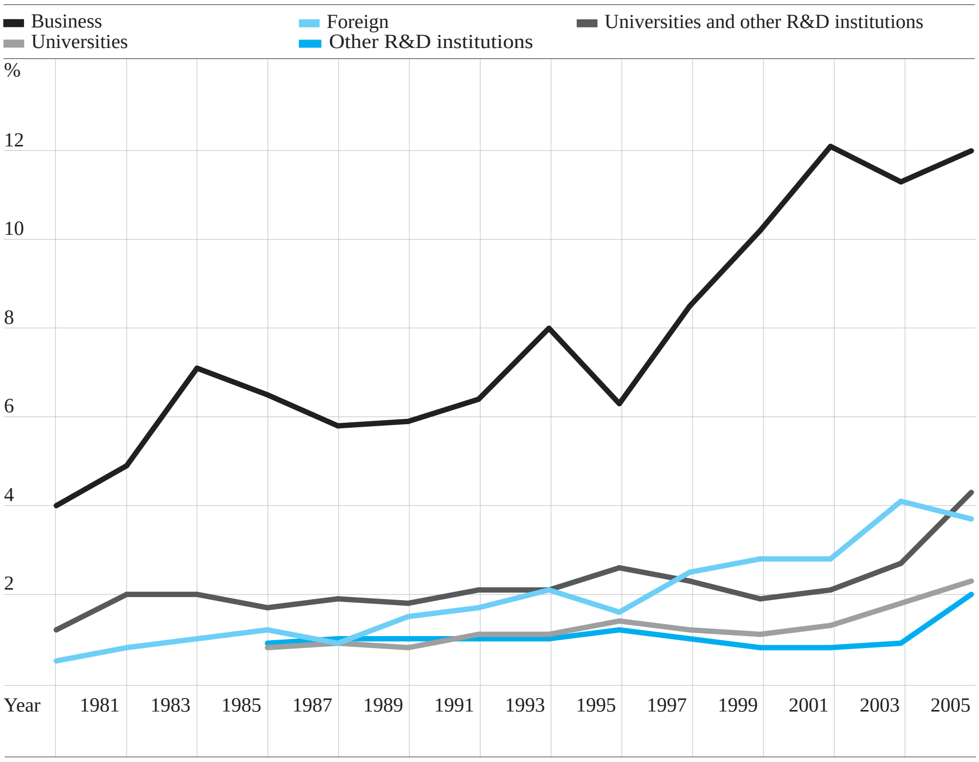
Reversal of decline in government support for R&D?

In recent years, increasing attention has been paid to research and development as a factor for the international competitiveness. Many states are now once again increasing their efforts in this sector, after withdrawing from R&D-financing over previous decades. Government contributions to R&D financing relative to GDP had fallen in the OECD member countries from 0.92 per cent (1985) to 0.83 per cent (1990) and 0.63 per cent (2000), and in Germany from 0.98 to 0.77 per cent over this period. Important reasons for this decline were the cutbacks in military R&D after the end of the Cold War, growing budgetary constraints, and the reduction of public funding for controversial large civil projects, in particular manned space travel and nuclear power.

In this decade, public R&D financing rates in the OECD increased to 0.66 per cent (2005). This is mainly due to increased state backing in the USA for basic research in the natural sciences and military research. This has provided extremely strong impulses. For example, research expenditure in the health sector in the USA was 34.5 billion US dollars (2005),

External R&D expenditure by sector of performance (as per cent of total R&D expenditure)

FIG 13



Source: SV-Wissenschaftsstatistik. Calculations by NIW.

compared with only 2.9 billion US dollars in Germany. There are not yet any signs in the German data of a trend towards more public R&D expenditure.

Increasing third-party R&D contributions

R&D processes in the economy have become an increasingly important competitive factor in recent years, however human resources and capital have also become more scarce. Business companies are therefore concentrating their internal R&D increasingly on their 'core competence' and outsource R&D assignments. Only 5.7 per cent of business R&D projects were being out-sourced at the end of the 1970s, but today this has increased to 20.3 per cent. This applies in particular for large companies. Overall, about 60 per cent of external assignments are placed with German companies, 18 per cent go abroad and some 22 per cent are placed with scientific institutions.

There has been a significant rise in orders placed with German companies since the start of the 1990s. This is a reflection of strategies to outsource activities of lower strategic importance to services companies or suppliers. There has also been an increase in R&D cooperation within corporate groups. Almost half of all R&D contracts are carried out with associated domestic or foreign companies.

Growing importance of universities as R&D cooperation partners

In particular since 2001, universities have become more important as R&D cooperation partners for business companies. The share of overall R&D expenditure going to non-university institutions had been declining since 1995, but has now risen again and has almost reached the level of the universities. It has to be borne in mind that the non-university institutions frequently provide supporting services for innovations which are not directly classified as research and development, and that as a result their importance for the innovation processes are considerably underestimated if only R&D projects are considered. Public institutions are above all an important partner for the external orders from SMEs. In general, external R&D activities increase with the level of technology involved. In cutting-edge technology, a particularly large proportion of R&D work is carried out by external commissions.

R&D expenditure currently increasing

In 2006, overall R&D expenditure increased by 7.4 per cent over 2005. The figures for 2007 are expected to show a further increase of 4.2 per cent. This is the start of a necessary process of catching up with a number of other countries who have steadily increased the proportion of added value spent on R&D. The rates of increase for 2006 and 2007 are above the rate of inflation and the growth rate of the gross domestic product; companies have invested more in research and development in real terms.

The numbers of personnel employed in R&D and innovation has been increased in 40 per cent of companies, and the total is expected to increase by 3.5 per cent. However, more than 20 per cent of companies were not able to recruit as many R&D personnel as planned. This is obviously already a consequence of the shortage of qualified specialists.

D 3 SPECIAL TOPICS OF RESEARCH AND DEVELOPMENT

The following section addresses three special topics which are closely related to research and development. Additional information is included on production, foreign trade, patents and publications.[79]

D 3–1 GERMANY IN GLOBALISATION

The past decade, in particular up to 2001, has been marked to a strong trend to globalisation. The German public have been increasingly worried about a growing trend for German companies to relocate production in other countries. But another key aspect is the relocation of R&D activities. In 2005, 76 per cent of R&D activities in Germany were being carried out by companies which did R&D in other countries. Ten years earlier the figure had been 69 per cent. On the one hand, companies who are not involved in the internationalisation of R&D have been contributing less and less in recent years to R&D in the German economy; on the other hand, increasing numbers of companies involved in R&D are also becoming active in other countries – a reflection of the growing export orientation of the German economy.

The internationalisation of the innovation activities of companies has in particular been reinforced in the second half of the past decade in a wave of transnational mergers and acquisitions. But of course many foreign companies have also been carrying out R&D work in Germany for a long time. Foreign companies spent EUR 1.2 billion more for R&D in Germany than German companies did in other countries. German companies carry out about a quarter of their R&D in other countries; equally, about a quarter of R&D activities in Germany are carried out by foreign companies.

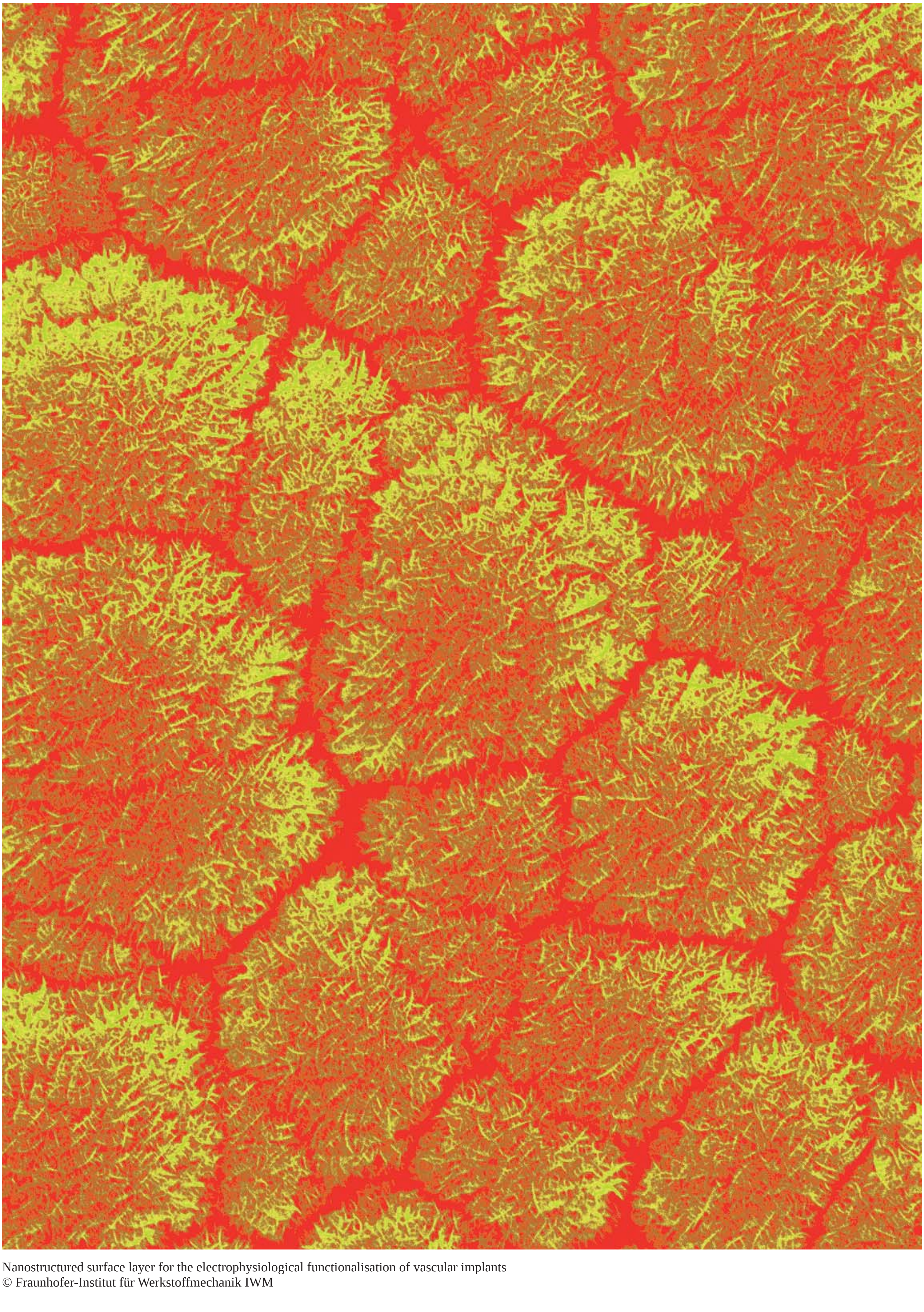
Germany is the second largest R&D location for foreign companies

After the USA (25.5 billion euros) and before Great Britain, Germany is the second most important R&D location for foreign companies with an expenditure of 12.6 billion euros.

Germany is also the second most important location after Great Britain for US-subsidiaries, and these show the highest R&D intensity in comparison with other location countries. In the dynamic of R&D expenditure by American companies, however, Germany and Great Britain are both far behind countries such as Sweden, Ireland, China, Israel, and Canada. Overall, Europe has become less important for R&D investments by American companies than locations in Asian newly industrialising countries.

Germany shows overall benefits from R&D globalisation and has proved particularly attractive for foreign subsidiaries. In the mid-1990s, foreign companies accounted for some 15 per cent of R&D potential in Germany, and this share has since increased to 26 per cent, mainly due to mergers and aquisitions from 1997 to 2001. These have resulted in existing R&D capacities being acquired and then extended in parallel to the activities of German companies. In recent years, the globalisation of industrial research in Germany has slowed down. Between 2001 and 2005 the

The coast of the Yellow Sea north of Shanghai



Nanostructured surface layer for the electrophysiological functionalisation of vascular implants share of foreign companies in research only increased slightly. Nevertheless, Germany has reached a high level of internationalisation for R&D in comparison to other large industrialised countries, only bettered by smaller countries, e. g. Switzerland, the Netherlands, Canada or Sweden, and also by Great Britain, with nearly half of R&D expenditure by foreign companies.

The importance of foreign companies for R&D capacities is greatest in the chemical industry, accounting for 32 per cent (including the pharmaceutical industry with 40 per cent), but levels of 26 per cent have also been achieved in the computer industry, electrical engineering, precision engineering, and in vehicle construction.

Foreign companies have about the same priorities for their R&D activities in Germany as their domestic competitors. In general multinational companies adapt their investment decisions to the structures of the country in question. This is also expressed in the research intensity, so that foreign companies have meanwhile reached the R&D intensity of German companies. In vehicle construction and mechanical engineering, they carry out research and development on average with a somewhat higher intensity. The greater emphasis on R&D rather than production activities in comparison with local competitors speaks for the very good conditions for R&D in Germany in the sectors in question.

The high level of internationalisation in the chemical and pharmaceutical industry not only leads to a large proportion of foreign companies in Germany, but also the involvement of German companies in other countries. In 2005, German chemical and pharmaceutical companies spent 40 per cent of their overall R&D budget in other countries. Indeed, for the pharmaceutical industry alone it was 55 per cent, mainly in North America, but increasingly also in Southeast Asia. At least until 2005 there was a general pause in globalisation for R&D, which can be interpreted as a period of consolidation after the very rapid globalisation. This should also be seen in the light of the fact that the R&D capacities in the USA in this period were reduced considerably in the highly globalised sectors of industry, and the rate of expansion after this was considerably reduced.

Since 2001, the proportion of R&D expenditure by German companies in other countries declined from 26.7 per cent to 24.4 per cent. Both the 'outward' and 'inward' internationalisation of R&D in multinational companies has come to a standstill in the new millennium. In spite of these moderate changes in recent years, a remarkable level of globalisation has been reached. German companies carry out about a quarter of their research and development in other countries, and conversely about a quarter of R&D activities in Germany are carried out by subsidiaries of foreign companies.

High R&D intensity of German companies in the USA

German companies have the second-highest R&D intensity in the USA after Swiss companies. This shows that in the USA not only market access is important but also the acquisition of knowledge, particularly for the cutting-edge technologies. This motive has grown in importance since the end of the 1990s. German companies not only see considerable potential for the future, but also the need to further expand their R&D in other countries. After some quiet years, it must therefore be expected that there will be increased international mergers and acquisitions (M&A) and thus a further diversification of the production and R&D locations. Worries that multinational companies could withdraw their R&D activities from Germany have so far proved unfounded.

The transnational networking of company R&D locations and the exchange of knowledge has so far taken place within and between the knowledge-intensive regions of the USA and Western Europe. 59 per cent of total R&D expenditure of foreign subsidiaries in Germany came from European companies and 38 per cent from North American ones, particularly in vehicle construction. R&D expenditure by companies from Asia and the rest of the world is of little significance in Germany so far, accounting for only two per cent. The involvement of the traditionally important target countries in worldwide R&D expenditure has already showed a slow decline in the case of American companies. Increasingly they are also carrying out their R&D in new dynamic economies. The proportion in Israel increased between 1999 and 2004 from 2.1 per cent to 3.6 per cent, in China from 1.6 per cent to 3.5 per cent.

German companies in almost all sectors expect to expand their R&D and innovation activities in other countries. But they are planning the expansion more in newly developed and emerging economies in Asia than in Western Europe. It is not possible yet to make any reliable predictions about the extent of this.

Gradual increase in direct investments also after 2000

There is little statistical data available about direct investments by German companies in other countries. According to the Bundesbank, in 2005 there were some 24 000 companies in other countries with German direct investments, of which 7 500 were in the manufacturing industries. An evaluation of a companies' database[80] suggests that in the case of the research-intensive manufacturing industries about 6.5 per cent of German companies with at least 20 employees have at least a ten per cent holding in one or more companies in foreign countries.[81] The corresponding figure for other manufacturing sectors is only 3.5 per cent. The percentage is also lower for technology-oriented service providers at 3.5 per cent. The level of 6.5 per cent for research-intensive industrial companies may seem modest at first sight, but there are a very large number of small enterprises in the dataset. Between 2002 and 2004 the proportion of companies with foreign direct investments has risen slowly. These investments are aimed initially at production in other countries, but will also involve research and development in due course.

D 3—2 ASIAN NEWLY INDUSTRIALISING COUNTRIES IN THE KNOWLEDGE ECONOMY

An important trend in recent years has been the rapid rise of the newly industrialising countries, in particular in Asia. High growth rates in small countries starting from a low base are a common phenomenon which at first has little effect on international developments. However, it is remarkable in this case that these countries have meanwhile achieved considerable weight, including in absolute terms, and this has worldwide consequences for innovation. The role of the Asian newly industrialising countries can be demonstrated by a comparison of gross domestic product. China is in second place behind the United States, in front of Japan and Germany, India is in fifth place (Table 03). The data used for the table is based on a recalculation of purchasing power parities,[82] and the gross domestic product of China is about 40 per cent lower than some earlier figures. This does not alter its importance and its strong growth rates for all economic data. But it will take at least another decade until China has reached the economic significance of the United States.

Strong growth of patent applications from Asia

There has been a marked increase in world market patents in Asian countries, in particular with Korea and China specialising in ICT. Korean patent applications have tripled since 2000, and Chinese applications have increased 2.5-fold. Looking only at high technology, the development for China is even clearer, underlining not only the focus but also the considerable potential of this economy in cutting-edge technology. Since these are international applications which have to meet the corresponding standards and which are exposed to international competition, these values and developments should not be underestimated. In absolute terms, China has already outstripped countries such as Sweden, Finland or also the Netherlands. Korean companies register three times as many patents in the USA as in Europe, but the Chinese companies have no exclusive focus on the American economy, and are equally involved in Europe.

Newly industrialising countries catching up in terms of publications

The growing activity of newly industrialising countries, and in particular China and Korea, is also reflected in a process of displacement in publications in internationally relevant journals, i. e. to a steady decline in the share of publications from the major industrialised countries. Since the year 2000, the rate for the USA has sunk by four per cent, that of Germany by ten per cent. In contrast, China's share has increased by 66 per cent, Korea by 62 per cent. It is also important to note that the citation indices for both Chinese and Korean publications, an indication of their quality, have meanwhile reached average levels, whereas Japan has had a significantly negative index since the start of the 1990s. However, the index for the international orientation remains definitely negative for South Korea and China, whereas here Japan is approaching an average level. Asian authors are increasingly succeeding in placing their publications in high-profile international journals. The data on patents and publications show an increased orientation of these countries to the knowledge-intensive sector.

R&D-efforts of the newly industrialising countries are rising significantly

This development is particularly marked for expenditure on research and development. The most important newly industrialising countries only accounted for a twelve per cent share of worldwide R&D expenditures, but by 2005 this had increased to 24 per cent (Figure 14). The newly industrialised (threshold) countries in this case consist of China and South Korea, eastern European countries such as the Czech Republic, Hungary or Poland, as well as Israel, Singapore, India, Brazil, Mexico and South Africa. The figures are still based on old purchasing power parities which make the growth seem more dramatic than it has actually been. But this does not alter anything about the massive increase and the high absolute impact that it is now exerting.

Among non-OECD countries, R&D intensity is particularly high in Israel (4.5 per cent), Taiwan (2.5 per cent) and Singapore (2.4 per cent). If the increases in R&D intensities in the established countries Japan and South Korea are also taken into account, the extent of the global shift towards Asia becomes clearer. The Asian states are meanwhile international engines of research and development. In India, spending on research has almost reached 28 billion euros, putting it in eighth place worldwide. Foreign investors are attracted in particular by the scientific tradition and the human resources. The government continues to play a dominant role in R&D, in particular in the military sector, agriculture, space research, health, and energy. Foreign companies often set up production-independent R&D centres in India, and with 26 per cent R&D is the most-frequently cited reason for foreign direct investments. The conditions are regarded as being particularly favourable in the sectors chemicals, pharmaceuticals, electronics, and software.

The growing importance of the newly industrialising countries, in particular China, is meanwhile also impacting on the German balance of trade. German imports from China have increased between 2000 and 2006 by a factor of 2.6, the German exports to China by a factor of 2.9. Currently, some seven per cent of German imports are from China, although to a large part these are products of German subsidiaries in China.

The orientation of the newly industrialising countries, in particular China and India, towards knowledge-intensive sectors is an opportunity for German companies, because these countries need investment goods to set up their industries which correspond well with the German specialisation profile. For this it will be necessary for German companies to maintain or even increase the current high innovation level. Japan is currently making efforts to withstand competition from its direct neighbours by increasing its research expenditure. This is probably also the best approach for Germany to adopt.

CONTRIBUTION OF SMALL AND MEDIUM-SIZED ENTERPRISES TO RESEARCH AND INNOVATION D 3 – 3

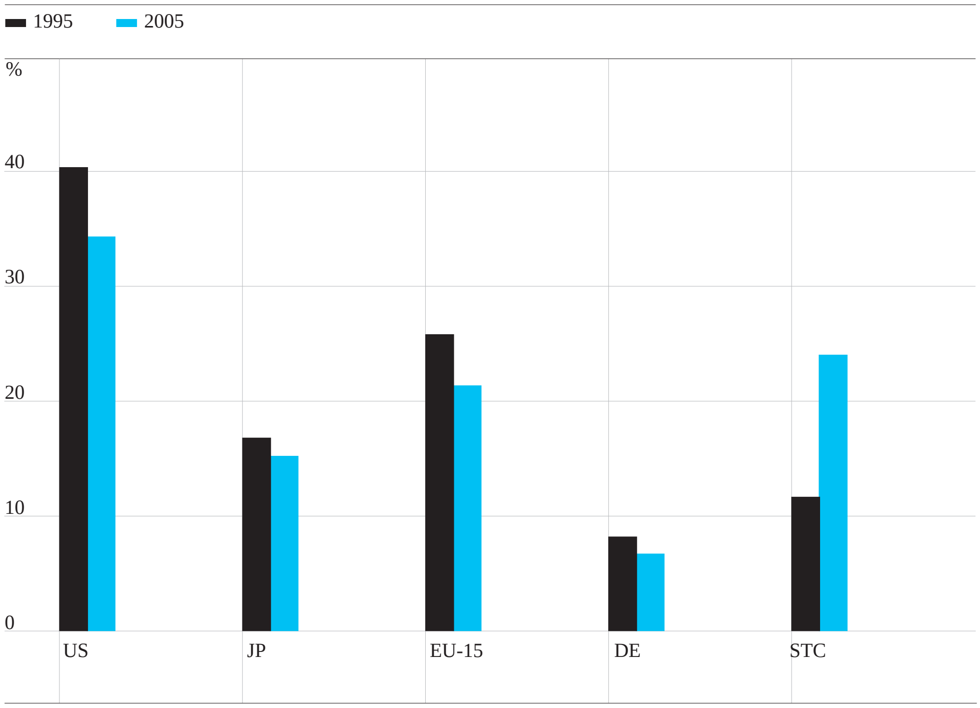
Large companies make a decisive contribution to the macroeconomic volume of innovations and R&D and also for the innovation and R&D intensity. The large numbers of

TAB 03 **Shares of the largest countries in the global gross domestic product, 2005 in dollars PPP**

Country	per cent
USA	23
China	10
Japan	7
Germany	5
India	4
United Kingdom	3
France	3
Russian Federation	3
Italy	3
Brazil	3
Spain	2
Mexico	2

Source: World Bank 2007.

FIG 14 **World regions and their shares of internal business R&D expenditure**



STC: Selected threshold countries, Calculations in current prices.
Source: OECD, Main Science and Technology Indicators (2007/2). IMD World Competitiveness Yearbooks (various). DST. IFM. Federal Office of Statistics, Statistisches Jahrbuch. Ministerio da Ciencia e Technologia do Brasil. Calculations and estimates of NIW.

small and medium-sized enterprises (SMEs) determine the extent to which the innovations and R&D are anchored in the economy. To this extent their R&D involvement is a critical parameter for innovation policy developers. However, there has been a long-term decline in the proportion of SMEs with R&D activities. The R&D activities are increasingly being concentrated in a relatively small number of large companies. In 1995, 21 per cent of the small industrial companies with less than 100 employees reported R&D activities, but in 2003 it was only twelve per cent. For the slightly larger companies with 100 to 500 employees, this proportion declined over the same period from 34 per cent to 29 per cent.[83] The R&D activities have thus lost breadth in the economy, although this process has slowed down recently.

In an international comparison, the regular participation of SMEs in R&D in Germany is still relatively high. However, this important advantage of the German innovation system has weakened in recent years, and the number of researching companies in Germany has been declining, while most other European countries have seen an increase. SMEs have increased their share of the external R&D expenditure between 1995 and 2005 from eight per cent to ten per cent, but are considerably below the values of the large companies (1995: ten per cent, 2005: 20 per cent). Within the external R&D of SMEs, universities receive more than 20 per cent of the commissions, a proportion which is comparable with that of large companies.

For international comparisons of R&D participation it is important to consider that the government contribution towards financing R&D in Germany has fallen steadily since the start of the 1990s from ten per cent to currently about 4.5 per cent. In absolute terms, a large part of state aid (78 per cent) goes to large companies, with the focus here on the aeronautics and astronautics industry. In general, since the mid-1990s large companies no longer receive preferential government treatment. On average, the intensity of state intervention, measured as the proportion of state aid in total R&D expenditure, in 2005 was 8.1 per cent for small enterprises, 4.2 per cent for medium-sized companies, but only 3.1 per cent for large companies. And with the overall decline in state aid for R&D, there is also a loss of leverage. Experience shows that every Euro of state aid for R&D will mobilise an additional 80 Eurocent of business R&D investment.[84]

Decline in innovation participation of SMEs

The rate of innovators varies with the size of the companies. For companies with more than 500 employees it is 90 per cent, for medium-sized companies with 50 to 500 employees 70 per cent, and 51 per cent of small industrial enterprises with 5 to 49 employees are innovators. This comparison shows clearly that the average of 58 per cent innovators for the manufacturing industry is strongly influenced by the large number of small companies. For the knowledge-intensive services the percentages in the three size categories are only slightly lower than those for manufacturing. However, in particular for small and medium-sized enterprises there is clear decline in the innovation participation. In absolute terms, the importance of the innovation expenditure of SMEs is limited. In 2006, SMEs provided only 28 per cent of all entrepreneurial innovation expenditure, in the mid-1990s their share had been about a third. As with R&D, there is a declining trend here. In the industrial sector, the proportion of innovations expenditure from SMEs is only 22 per cent, but it is considerably higher in the knowledge-intensive services with 42 per cent and other services with 41 per cent. It would seem that SMEs are considerably more important for service sector innovations than for the manufacturing sector. In terms of successes with market innovations, SMEs reached peak values in both manufacturing industry and in knowledge-intensive services in the years 2000 and 2001; since then, however, they have declined considerably.

Tax support for R&D increasingly significant internationally

As has already been mentioned, many other OECD member countries have also been reducing their direct state contributions to R&D financing since the start of the 1990s. However, there has been a shift in many countries to more indirect state aid for R&D by means of tax credits or tax allowances. Indirect R&D aid is regarded as a good way of broadening the base of companies carrying out R&D, in particular among small and medium-sized enterprises. A number of countries which already offer more state aid for R&D by SMEs than for large companies have recently also introduced fiscal R&D aid. In 1995, twelve OECD member countries used indirect tax aid, but in 2006 the number had risen to 20. Considerable funds have been mobilised. In 2005, direct state financial aid for

R&D in enterprises in Austria accounted for 6.4 per cent of expenditure, but including tax aid it amounted to 17.4 per cent. In Great Britain the figures were 8.6 per cent and 12.9 per cent, and in the USA 9.7 per cent and twelve per cent, respectively. The conclusion is that in recent years the state R&D aid for SMEs in other countries has progressed more than in Germany.

D 4 INNOVATION AND PATENT BEHAVIOUR IN THE GERMAN ECONOMY

D 4 – 1 INNOVATION BEHAVIOUR IN THE GERMAN ECONOMY

In the context of companies the concept of innovation refers to bringing new goods and services to the market and introducing new processes. Whereas research and development generate new knowledge, innovations involve the development of market-relevant products and their marketing. This section presents key results of a recent annual company survey.[85]

Innovator rate in long-term decline

Despite improving economic conditions, there was no increase in the proportion of companies in Germany with product or process innovations in the manufacturing and services sectors in 2006, and the figure remained at about 46 per cent. Differentiated in terms of sectors, the innovator rate was highest in the manufacturing industries at 58 per cent (Figure 15). For the knowledge-intensive services it fell to 52 per cent (from 55 per cent in the previous year). Here the innovation participation of companies has been very irregular in recent years, which is an indicator perhaps of a shorter-term orientation of innovation activities. For other services the innovator rate rose slightly, but at 33 per cent it is much lower in this sector than in manufacturing or the knowledge-intensive services. Many companies can obviously achieve market success without continuous innovation activity.

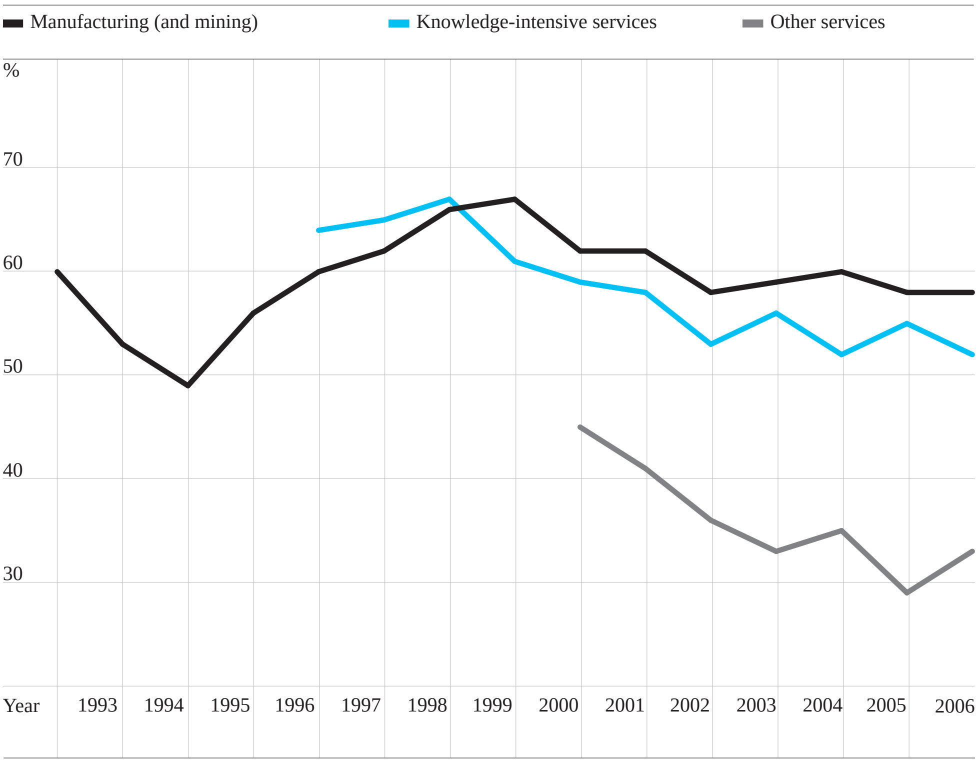
Innovation activities can either aim at introducing new products or new processes within the company for production, service provision, or marketing. Within a three-year period, a considerable proportion of the innovators – 47 per cent in the industry sector, and some 40 per cent in the services sector – realised both product and process innovations. 20 per cent to 25 per cent of the innovators introduced only process innovations, and 35 per cent to 40 per cent are solely product innovators.

Decline in innovations after the New-Economy boom

For the first time in some years, a slight rise could be observed in 2006 in the numbers of companies introducing products new to the market. These are companies launching at least one innovation on the market which none of their competitors had previously offered in this or a similar form. It is not sufficient for the commodity in question to be a novelty for the company in question. The proportion of product innovators rose to 47 per cent in the manufacturing sector and to 31 per cent for other services; in the case of knowledge-intensive services it fell slightly to 33 per cent.

The overall proportion of companies innovations new to the market decreased over the past seven years – obviously it is becoming more difficult to market original new products. The high figures at the end of the 1990s are related to the dynamism of IC technology in that period. As with production, balance of trade, and R&D, the figures for innovations clearly reflect the effects of the New-Economy boom and its collapse in 2001. As already noted for

Innovator rates in the German economy FIG 15



Source: ZEW.[86]

the international comparison of labour productivity, Germany lags behind Japan and the United States when it comes to introducing original new products.

Increasing innovation expenditure

Although there has been a long-term downward trend in the innovator rate in all sectors since 1999, for some years there has been a continual increase in innovation expenditure. The value of EUR 115.5 billion in 2006 is nominally 6.3 per cent more than in the previous year, and was considerably larger than the companies had been planning at the start of 2006. This shows that they took short-term decisions to reallocate resources in favour of innovation activities. This observation corresponds to the pro-cyclical behaviour already noted for R&D activities. The increasing innovation expenditure coupled with a declining innovator rate is due to the growing concentration of innovation activities in large companies.

Nearly three-quarters of innovation expenditure, namely 72 per cent, was in the manufacturing sector, where the innovation budgets increased by more than 5 per cent over the previous year. There was the same rate of growth in the budgets for knowledge-intensive services, so that this sector accounted for 19 per cent of overall entrepreneurial expenditure on innovations. Other services experienced a jump in their innovator rate, and innovation expenditure also increased by 11 per cent, so that 7 per cent of the overall innovation expenditure came from this sector.

For 2007, the plans of the companies from the start of the year indicated a further increase in innovation expenditure of 5.5 per cent. The projected rise for the knowledge-intensive sector was higher (+7 per cent), while the innovation budgets in the other services were to be reduced again. In the manufacturing sector, the increase of about 6 per cent corresponds roughly with the average planned growth for the total commercial economy.

Increasing innovation intensity of knowledge-intensive services

Despite the rise in innovation expenditure in 2006, there has hardly been any change in the relationship of innovation expenditure to revenue, the so-called innovation intensity. However, in the case of knowledge-intensive and other services the growth in innovation expenditure was greater than the rise in revenue. Although there has been a decline over the medium-term in the innovation intensity in the manufacturing sector and the other services, there has been continual growth in the knowledge-intensive services.

Of the innovation expenditure, 34 per cent was spent on investments in property, plant and equipment, or intangible assets. In the late 1990s this investment rate had been 45 per cent. This means that a disproportionately high amount of the additional innovation expenditure is going towards costs for personnel, materials, and preparatory performances (including outsourced work).

In general, process innovations can serve two purposes – either new processes are aimed at reducing costs through more efficient production of goods and services, or they have the goal of improving quality. In all three sectors of the economy considered here, the proportion of process innovators who achieve an improvement of quality is higher than the proportion of rationalising innovators. In the manufacturing industry, 71 per cent of process innovators produced quality improvements, 72 per cent in the knowledge-intensive services, and 54 per cent in the other services. These figures have been more or less constant since the year 2000.

Slightly increasing contribution to turnover with product innovations

The direct economic success of product innovations can be measured by the contribution to turnover achieved with the newly introduced products. In order to allow for the time lag between introducing an innovation and any increase in revenue, all products are considered which have been introduced over the previous three years. The contributions to turnover in the manufacturing sector and in the knowledge-intensive services showed slight increases in 2006, with a rate of 28 per cent for the former and 14 per cent for the latter. Other service providers achieved an increase of about 1.5 per centage points to 7.5 per cent.

The share of turnover of new products on the market, often referred to as the innovation rate, is influenced to a considerable extent by the sales of imitations. The turnover of market innovations, on the other hand, measures the contribution of original product innovations to overall turnover. This figure is much lower than the share of turnover achieved with new products. In 2006, original market innovations in the manufacturing sector generated 6.4 per cent of total turnover, slightly less than in 2005. In the knowledge-intensive services it remained constant at 4.7 per cent. A longer-term comparison shows a falling trend in all three sectors examined, as seen with the proportion of innovative companies. In other words there has been an overall drop in the level of innovation in products.

Research and development are key components of innovation expenditure

Research and development are key components of innovation activities. Almost 50 per cent of all innovation expenditure is on internal or external R&D, with a higher proportion in the

World market patents BOX 16

These are patent applications aimed at obtaining protection in a large number of countries. For this purpose, application at the World Intellectual Property Organisation (WIPO) and additionally at the European Patent Office are evaluated.[87] Because of the complex legal procedures involved and the higher costs, international patents often cover inventions with greater technological and economic relevance than is the case for national applications.

manufacturing sector and a lower proportion in the services sectors. The proportion of companies which continually run in-house R&D is a measure of the innovation activities aimed at the creation of new knowledge and is thus an indicator of the need to develop new technologies and methods for innovative projects. The R&D involvement of German businesses fell in 2006. In the manufacturing sector the proportion of continually researching companies was down slightly at 23 per cent. For the knowledge-intensive services the downward trend which had been observed since 2004 was not continued, and 15 per cent were involved in R&D in 2006.

Importance of innovations for marketing and organisation

The OECD redefined the concept of innovation in 2005 so that in addition to product and process innovations it also covered new methods of marketing and organisation. The Mannheim Innovation Survey in 2007 took these innovation activities into account for the first time in Germany, and reported that 56 per cent of manufacturing companies had made marketing innovations in 2006, and 60 per cent had made organisational innovations (Figure 16). Each type of innovation is thus about as prevalent as product and process innovations are together. The proportion of companies who have introduced at least one marketing or organisational innovation is 73 per cent, which is considerably higher than the conventional innovator rate of 58 per cent (Figure 16).

For these new types of innovation, the ranking of the three main sector groups considered here is research-intensive manufacturing, followed by knowledge-intensive services, and then other services. This is the same as for the product and process innovations, but the gaps between the sectors are smaller.

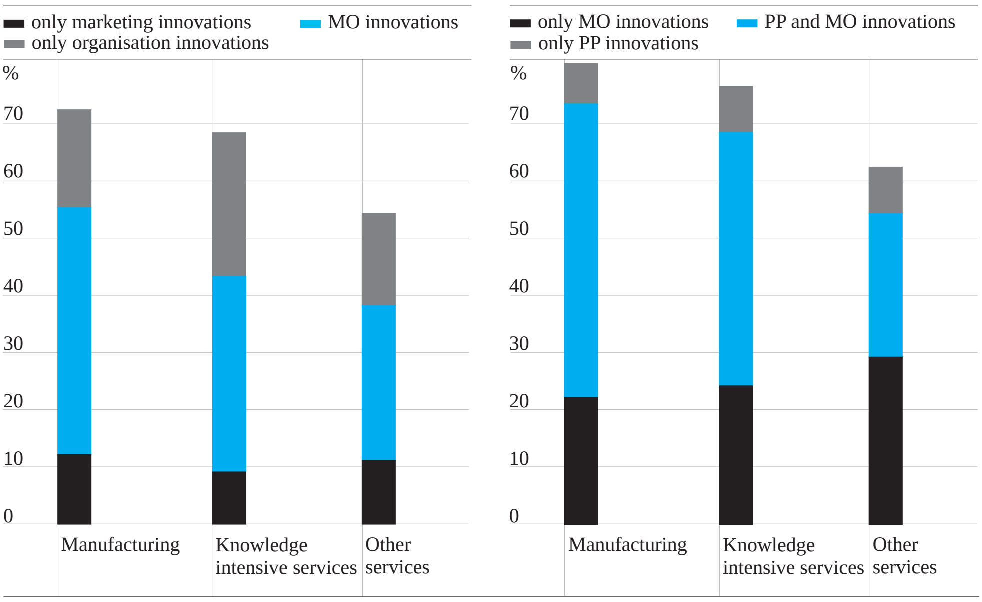
GERMAN PATENTS IN INTERNATIONAL COMPARISON D 4 – 2

Patents are innovation indicators which reflect primarily the output of technological activities, that is of the research and development and innovation activity. Patents serve to protect market advantages over competitors and their numbers are therefore always linked to the strategic importance of a national market sector. Therefore it is significant where an application is registered. The following sections consider world market patents.

Peak of patent applications in the year 2000 exceeded again

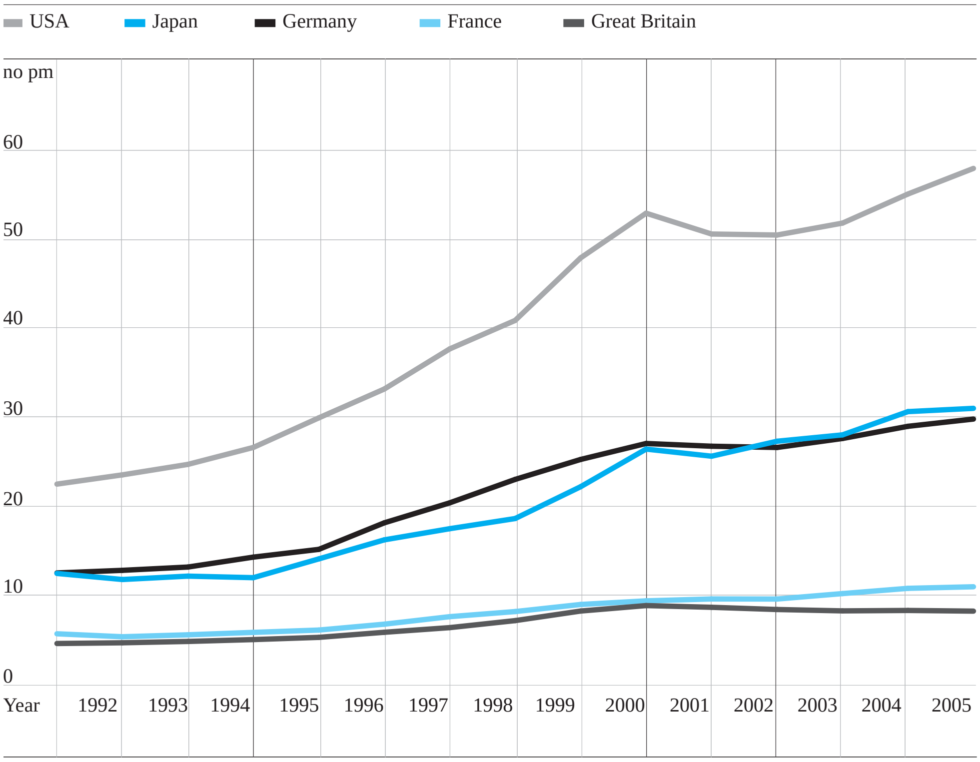
There have been three key phases of development since the mid-1990s. Firstly, there was a period of growth in the second half of the 1990s (Figure 17). This was related to the increasing relevance of technology in the competition between high developed countries and the growing strategic importance of patents. In addition to the protection which patents offer to inventions, they can also block the technological activities of competitors, secure an institution's expertise in cooperation projects, provide motivation for personnel, or increase creditworthiness. At the same time the euphoria of the New-Economy boom also stimulated patent applications, so that in this phase patent applications were increasing at a faster rate than research and development.

FIG 16 **Companies with marketing and organisation innovations**



PP: Products and processes, MO: Marketing and organisation.
Source: Rammer und Weissenfeld (2008).[88]

FIG 17 **International patent applications for selected countries**



Source: EPPATENT and WOPATENT databases (Questel-Orbit). Calculations by Fraunhofer ISI.

When the New-Economy boom collapsed, patent applications stagnated or even declined slightly, like other innovation indicators. Since 2003 there has been another phase of less dynamic growth, so that in most countries the level of 2000 has meanwhile been exceeded again.

Strong position of Germany for international patents

A comparison of absolute figures of large countries shows the leading position of the United States, which has been going through a dynamic phase of patenting recently. Germany and Japan have also shown a rising trend in the past few years. Japan would have been expected to show a stronger increase in patent applications in view of the considerable growth in research and development. At first sight it may seem surprising that Germany and Japan have very similar levels, because the Japanese economy is about twice the size of Germany's. But Japan is less strongly export-oriented than Germany and is also linked quite closely with the American market. German companies, in contrast, trade with a broad spectrum of countries, and therefore are more interested in broader patent protection. In recent years, France has shown a slight upwards trend, whereas the numbers for Great Britain have fallen slightly, even after 2002 in a period when most countries recorded a growth in patent activity.

If the national patent statistics are adjusted to take into account the size of the country, Switzerland has a clear lead in international comparisons (Table 04), followed by Germany, Sweden and Finland, with Japan and the USA ranking lower. These figures demonstrate the technology-orientation of Swiss companies, and they also show that the Swiss are more directed towards the global market than German companies. In the cases of Sweden and Finland, the specialisation in the cutting-edge technology of telecommunications plays a role. The position of the USA may seem at first sight to be surprisingly low, but much of its technological activities are directed primarily towards the domestic market and less towards exports. If only patents in the high-technology sector are considered, the ranking is the same, but the differences between countries are smaller.

In general, there has been less growth in high-technology patents than in the total number of patents since 2000, and in Sweden, Finland, and Great Britain there has actually been a clear decline. Here we can still see the damping effect of the collapse of the New Economy boom.

Intensity of world market patents for selected countries, 2005 TAB 04

	Total	High-technology
Switzerland	1057	440
Germany	767	365
Sweden	765	349
Finland	762	437
Netherlands	573	238
Japan	485	234
France	436	212
United States	402	210
Korea	371	211
Great Britain	265	126
PR China	6	3

Applications per one million employees.
Source: Databases EPPATENT, WOPATENT (Questel-Orbit).
Calculations by Fraunhofer ISI.

Stagnation in Germany's specialisation in high-level technology

The analysis of German patents in terms of high-level technology, cutting-edge technology, and high technology overall shows a specialisation in high-level technology, as already noted for production, foreign trade, and research and development. In contrast to foreign trade specialisation, where there has been a slight downward trend since the start of the 1990s, there was a period of growth for patents, followed since 2000, as with foreign trade, by a period of stagnation (Figure 18). The close link between patent specialisation and foreign trade specialisation shows that the current situation can only be maintained by continuous efforts with regard to innovations. The stagnation of the patent specialisation for Germany, despite increasing numbers of patents, is due to the fact that other countries have also augmented their efforts in this sector.

For cutting-edge technology, the specialisation index is very negative, as were the specialisation indices for foreign trade, and research and development. In total, the level of German patents for high technology is close to the world average, but in contrast to foreign trade specialisation it is still slightly negative. This is because cutting-edge technology has a higher weight in patents compared to high-level technology and therefore has a greater effect on the sum of both sectors, that is high technology (see Box 04).

Strong specialisation in automotive technology, weak values in ICT

Patents can be used to obtain a fine differentiation in terms of sub-sectors. A profile of German patent specialisation shows which fields contribute to the strengths and weaknesses in the high-technology sector. As in the analysis of research and development, the automotive sector is in first place, and engines, motors, and drive technology also ranks highly (Figure 5). These are followed by sub-sections of mechanical engineering such as machine tools or special machines. In measuring and control technology, the strength of high-level instruments is apparent, whereas the advanced instruments category has an index which is slightly below the world average. In the cutting-edge technology, the patent analysis shows negative values for computer equipment, telecommunications, radio and television technology, and also for biotechnology and pharmaceuticals, which illustrates the technology background to the relatively low values of the cutting-edge technology for other innovation indicators classified by products or economic sectors.

D 5 NEW ENTERPRISES

The entrepreneurial dynamic is an important aspect of the technological structural transformation. The foundation of new companies as well as the closure of companies which are not successful can stimulate competition for the best solutions.[89]

New enterprises with new ideas can extend and modernise the range of product and services on offer, and they are a challenge to existing companies. New enterprises in research and knowledge-intensive sectors of the economy have a special significance. However, bringing new ideas onto the market also involves risks and uncertainties. The competition among young, innovative companies and with established companies can be intense, and inevitably some of the new enterprises will not be able to survive in the long term. But even 'failed' new enterprises contribute to structural change. The business ideas they introduced and the innovative options they chose have either failed or they have been adopted more successfully by other companies, and possibly marketed in an improved form.

There have been various phases of starting up new enterprises in Germany. The numbers of start-ups remained fairly constant from 1995 to 1998. They then declined by an average of five per cent per annum between 1999 and 2002, and increased markedly in 2003 and 2004 by about ten per cent per annum, before returning in 2005 and 2006 to the level of 1995.

Fewer foundations of knowledge-intensive enterprises after the New-Economy boom

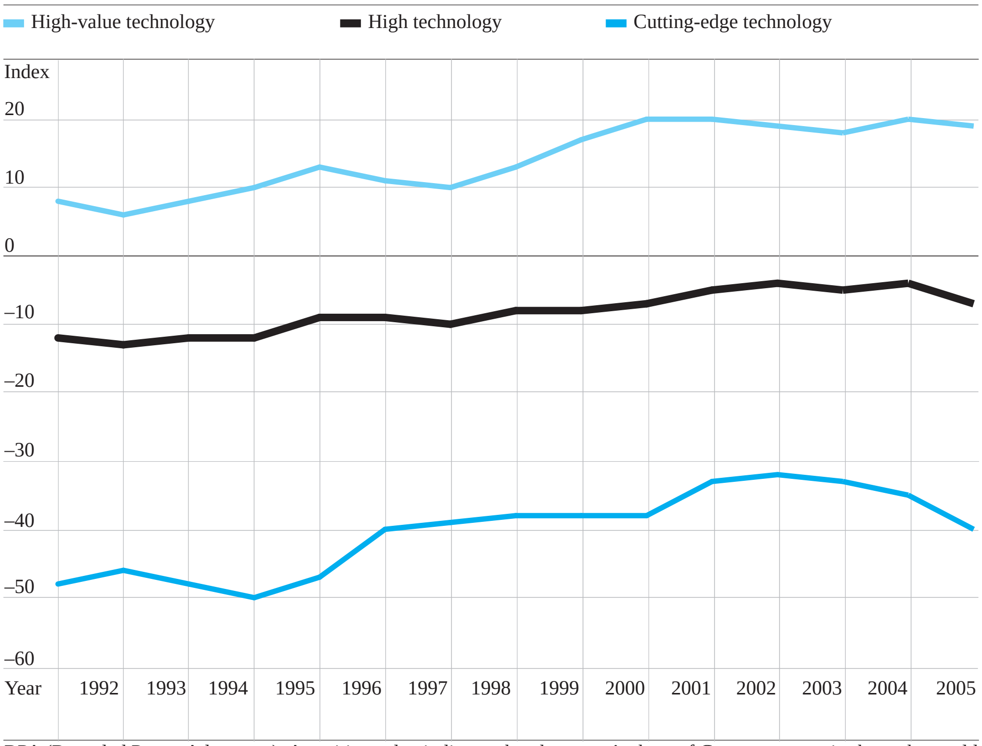
In 2006, 13 per cent of all new enterprises were involved in knowledge-intensive services, whereas the research-intensive manufacturing sector only accounted for about one per cent. From 1995 to 2000 the share of the new enterprises which were in the knowledge-intensive services had increased from 13 per cent to more than 15 per cent. There was a small surge in the foundation of new enterprises in 1999 and 2000, in particular for ICT services. This was clearly attributable to the New-Economy boom. When this collapsed, the trend was reversed and the share of the knowledge-intensive services declined significantly until 2004.

Knowledge-intensive services can involve knowledge-intensive consultancy (management, law and finances, advertising) and the technology-oriented services (telecommunications, computers, office technology, R&D-services). The technology-oriented services were affected by the New-Economy boom and bust, whereas the knowledge-intensive consultancy services proved more stable and are currently slightly ahead of the levels in the mid-1990s (Figure 19).

The proportion of the new enterprises which are in the research-intensive manufacturing sector has declined steadily since the mid-1990s, and only began to increase again slightly in 2006. But the absolute numbers of new enterprises have hardly been affected by the research-intensive manufacturing sector, i. e. the classic cutting-edge technologies such as pharmaceuticals and biotechnology, medical engineering, metrology/optics, electronics, or aeronautics and astronautics. It would be premature from the slight increase in 2006 to expect a new wave of technology start-ups, because

Specialisation (RPA) of Germany in high-technology sectors

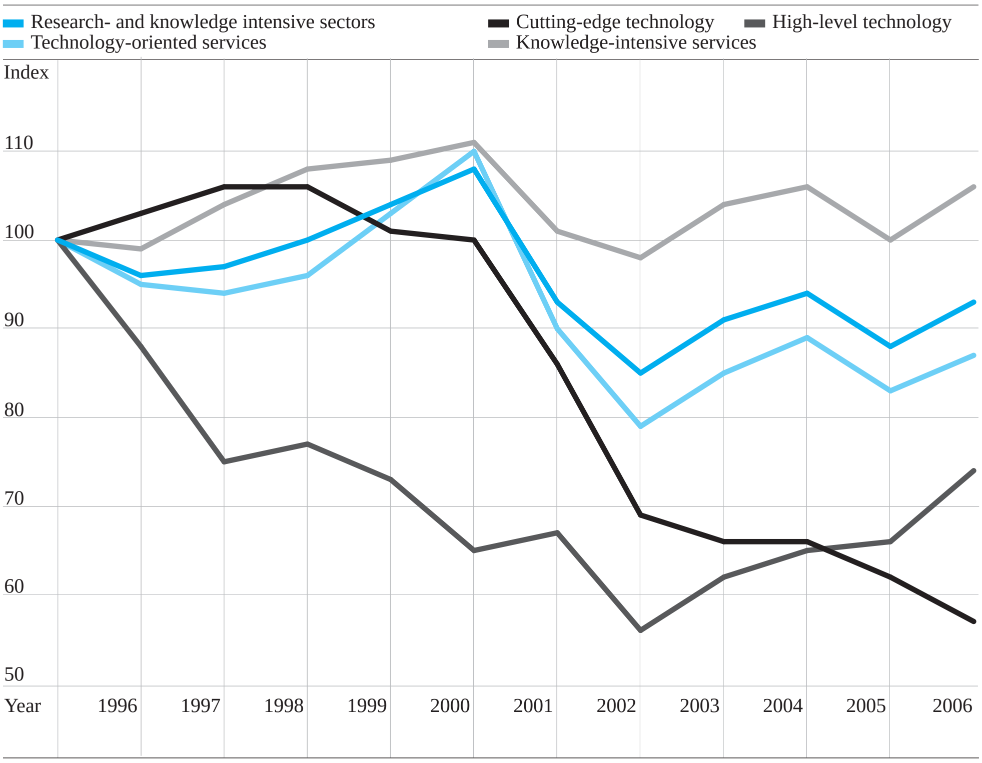
FIG 18



RPA (Revealed Patent Advantage): A positive value indicates that the sector's share of German patents is above the world average.[90]
Source: Databases EPPATENT, WOPATENT (Questel-Orbit). Calculations by Fraunhofer ISI.

New enterprises in Germany in research- and knowledge-intensive sectors

FIG 19



2006: provisional values. 1995 = 100.
Source: ZEW-Gründungspanel. Calculations by ZEW.

the current levels are still well below those at the start of the decade.

High barriers to starting up in the research-intensive manufacturing sector

The start-up rate, the number of new enterprises as a proportion of all companies, is an indicator of the regeneration of a sector of the economy. The figures show that the start-up rates for the knowledge-intensive services (technology-oriented services seven per cent, knowledge-intensive consultancy eight per cent) are much higher than those in research-intensive manufacturing (four per cent). The low start-up rate for the research-intensive manufacturing sector is an indication of the comparatively high barriers to entering this sector. In addition to the demands up-front for property, plant and equipment and to cover the development of products, entrepreneurs also encounter difficulties dealing with financing and recruiting a workforce, and in many market sectors will also have to confront the dominance of large companies. In the case of knowledge-intensive services the barriers to starting up are usually lower, both in terms of finance and also human resources, and in most sectors the competitors will be other small companies.

Numbers of company closures now declining again

At the same time as new enterprises are starting up, other companies are closing down. Annual closures increased steadily in Germany from 1995 to 2004, peaking at 290 000. In 2005 and 2006 there was a slight decrease. At first sight it seems surprising that numbers of closures increased even during the economic upswing at the end of the 1990s. A reason for this could be the competition between small companies following the relatively large numbers of new enterprises started in the 1990s. The numbers of closures rose sharply in the period of economic stagnation in 2001 and 2002.

Above-average numbers of knowledge-intensive service companies closed down, and their share of all closures increased from seven per cent in 1995 to nearly twelve per cent in 2001. Since then the proportion fell again to ten per cent (2006). Research-intensive manufacturing companies accounted for 1.5 per cent of closures in (1995) but this declined to 0.7 per cent in 2006. For cutting-edge technology, knowledge-intensive consultancy and technology-oriented services the closure dynamic basically followed the general pattern. In the case of the high-level technologies the numbers of annual closures remained virtually constant from 1995 to 2005, but there were fewer closures in 2006.

From 1995 to 2005 the annual closure rates (the number of closures in a year proportional to the numbers of companies in the sector) in the research und knowledge-intensive branches of the economy were below the general average. The rates were particularly low for cutting-edge technology and high-level technology.

Positive development of company stock in the knowledge-intensive sector

The relationship between start-ups and closures can be used to assess the entrepreneurial dynamics of a sector and these are important indicators of technological potential, showing the direction and the extent of structural change. The rate of change of the company stock, which corresponds to the balance of start-up and closure rates, was positive for the economy as a whole from 1995 to 2001, and for the research- and knowledge-intensive sectors, in other words the annual average of the number of active companies in Germany increased. Since 2002, the total numbers of companies in all sectors have declined year on year, and only increased again slightly in 2006. In the research- and knowledge-intensive sectors of the economy, in contrast, the number of companies decreased in 2002, but then start-ups and closures balanced each other out in 2003, and numbers began to increase again from 2004 onwards. Among the research- and knowledge-intensive sectors, the knowledge-intensive services had the most positive development in the numbers of companies.

Germany in a medium position as to start-up rates

An international comparison of start-up rates is a good way to assess the developments in Germany. The start-up rates, the number of new enterprises as a proportion of all companies, prove to be a good basis of comparison, because the differences in the definition of enterprises between countries are to some extent equalled out. The highest start-up rates among the 15 selected countries were in Great Britain, France, and the USA, where start-up companies in 2003 or 2004 represented 12 to 14 per cent of the total number of

Glass fibres

Deformed aluminium profile

companies. The start-up rate in Germany was eight per cent in 2004, which gives it a medium-to-low ranking; Japan (two per cent) and Switzerland (three per cent) had by far the lowest start-up rates.

For research-intensive manufacturing, Great Britain and the USA came out top, but Germany had a relatively low rate here of about three per cent, and only Japan had a lower value with 1.5 per cent. In all countries except Great Britain the start-up rates for knowledge-intensive services were above those for their overall economy. The highest rates are in Denmark, Norway, Great Britain, the USA, and France. Germany again finished well down the rankings in this category, with a start-up rate of about eight per cent.

Relatively low German closure rates

Not only are start-up rates in Germany comparatively low, but so are closure rates in an international comparison. This is not surprising, because high barriers to market entrance also act as protective barriers for those already inside. With an average value of eight per cent over all sectors, the numbers of closures as a proportion of all companies is much smaller than in Great Britain, France or the USA. General closure rates are only lower in Sweden, Japan, Portugal, and Switzerland. In the research-intensive manufacturing sector, Germany had a closure rate of about four per cent in 2004 – the lowest level behind Switzerland and equal with Sweden. A closure rate of seven per cent in the knowledge-intensive services in Germany was a medium value.

Moderate German company turnover

The comparison between countries shows that high start-up rates tend to go together with high closure rates, just as low start-up rates go together with low closure rates. It is therefore not possible to conclude from high start-up rates that the numbers of companies are increasing rapidly. The countries with a dynamic company structure (i.e. low barriers to market entrance and exit) include the USA and Great Britain, and also France, the Netherlands, Norway and Denmark. This applies both for the general economy and the research-intensive and knowledge-intensive sectors (Figure 20). An indicator for this is the company turnover – the sum of start-ups plus closures in relation to the number of companies. For the research-intensive manufacturing sectors, only Japan and Switzerland were less dynamic than Germany, although for the knowledge-intensive services Sweden, Spain, Portugal, Japan, and Switzerland were all behind Germany.

In addition to the structure and intensity of the start-up activities, the development of the start-up numbers over time is another important measure for international comparisons of start-up dynamics. The analysis of the data for Germany shows a marked decrease in the numbers of start-ups in the research-intensive manufacturing sector over the past ten years, whereas there was increasing start-up activity in the knowledge-intensive services in 1999/2000 and again since 2002. The other major economies with specialisation in knowledge-intensive economic sectors, i.e. USA, France, and Great Britain, show a basically similar development. However, Germany is somewhat less dynamic both in the general economy and in the research- and knowledge-intensive sectors.

In the research-intensive manufacturing sector Germany and the other large economies have decreasing numbers of start-ups. However, nowhere was this decline as pronounced as in Germany.

Even in the USA, there was a decline in the research-intensive manufacturing sector. This is in stark contrast to the public attention paid to the foundation of new companies in biotechnology and the computer industry. A few very dynamic sectors are not enough to start a general start-up boom.

Favourable development of company stock also in international comparison

Despite the lower start-up rates and weak company dynamics, the company stock in Germany grew more through until 2001 than in the comparison countries. In 2001 the level was 18 per cent above that in 1995, compared with a net increase of 8 per cent in Great Britain, and of five per cent in both the USA and in France. The larger number of company closures in 2002 and 2003 in Germany coupled with lower numbers of start-ups led to a drop in the number of companies, while numbers continued to increase in the USA and above all in Great Britain. Overall, however, the company situation in Germany is favourable, because the closure rates are still considerably lower than in the other countries.

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]

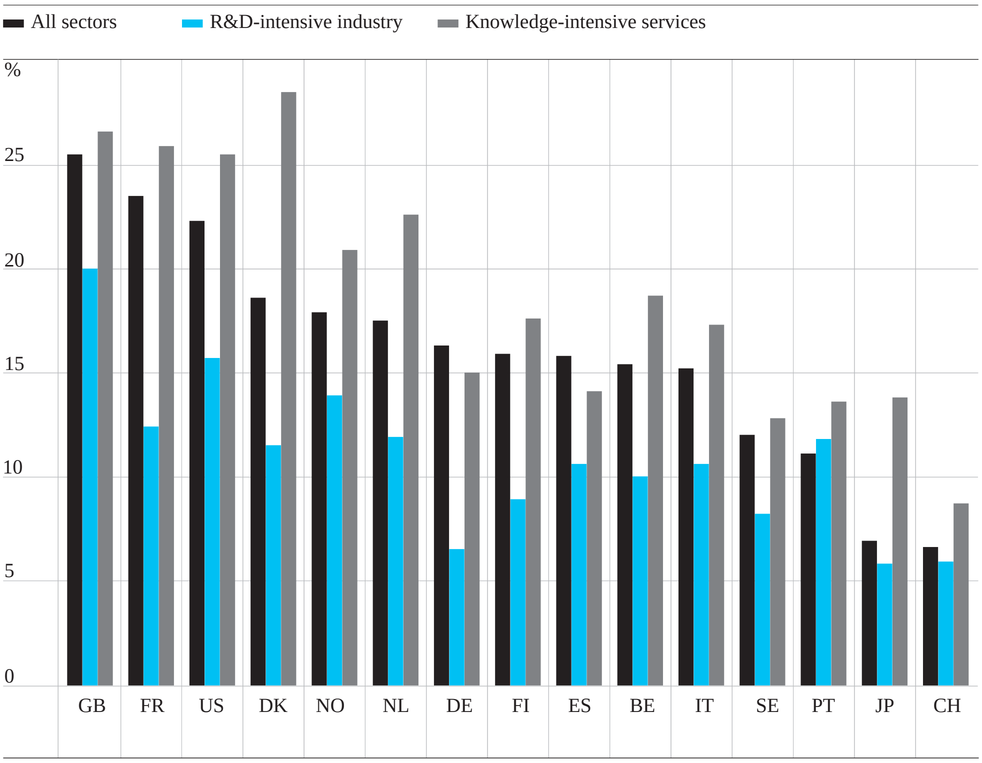
Increasing numbers of graduates due to knowledge intensification

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.

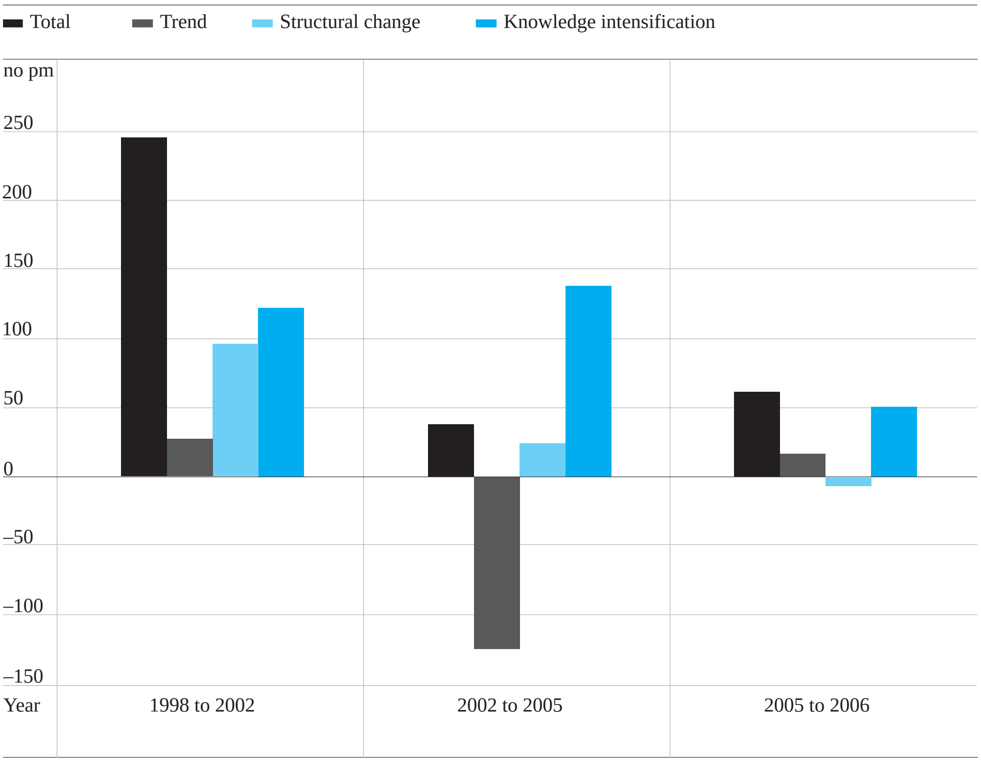
More new students enrolled in 2007

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

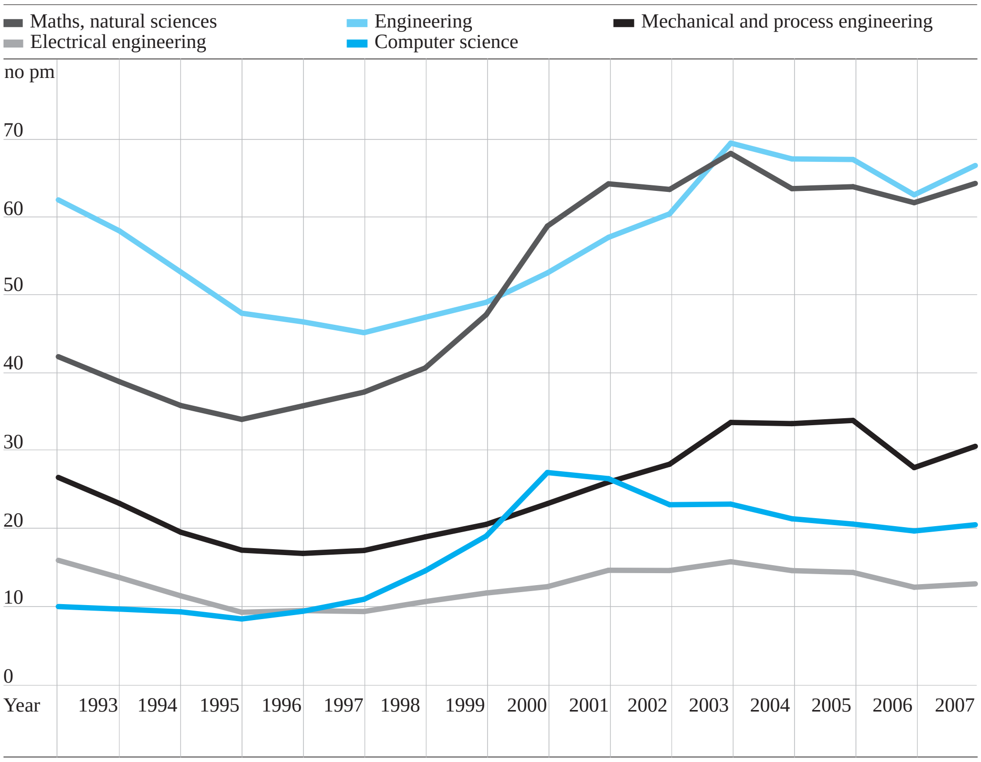
FIG 21



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 7 000 engineering students and more than 13 000 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 86 000, 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 550 000 in 2005 to 576 000 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 100 000 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.

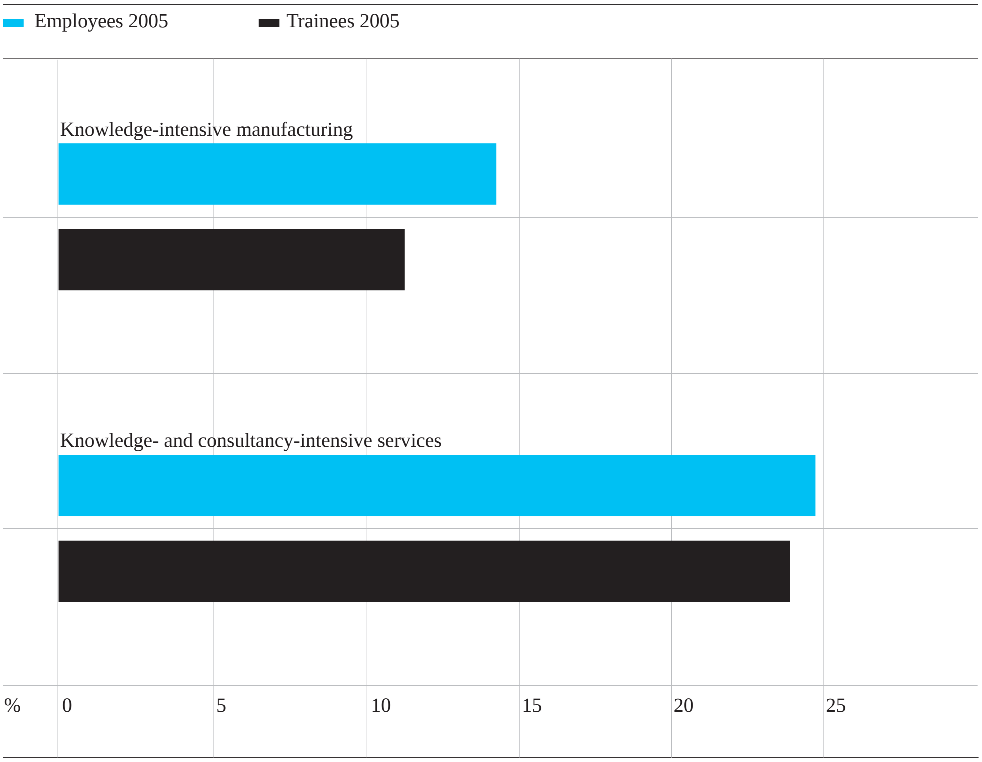
Taking the international alignment, a further citation-based indicator, German authors have increasingly been participating in the international discussions, and publishing in prominent international journals. This trend has probably also been due in no small part to the increased attention paid to publication- 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.

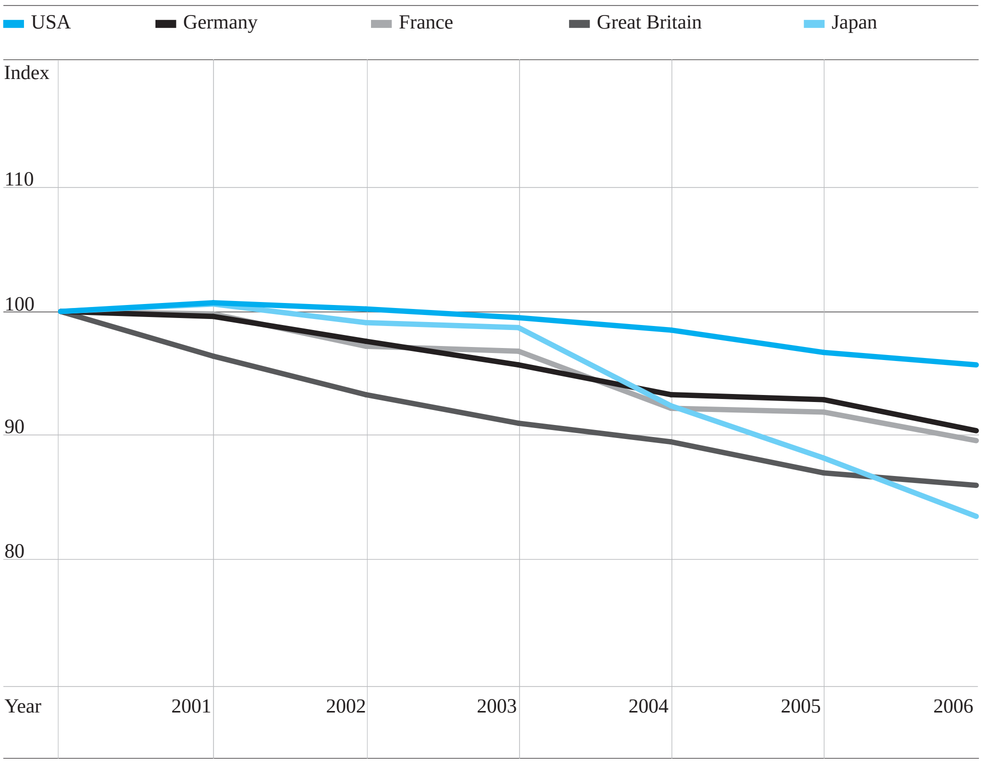
International co-publications have increased in numbers over the past 15 years. This applies also for German authors and in particular for joint activities within the EU member states.

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.

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LIST OF ABBREVIATIONS

BDI	Bundesverband der Deutschen Industrie e.V.
BIBB	Bundesinstitut für Berufsbildung
BMBF	Federal Ministry of Education and Research
BMELV	Federal Ministry of Food and Agriculture and Consumer Protection
BMF	Federal Ministry of Finance
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMVBS	Federal Ministry of Transport, Building and Urban Affairs
BMWi	Federal Ministry of Economics and Technology
BMZ	Federal Ministry for Economic Cooperation and Development
CO_2	Carbon dioxide
DIW	Deutsches Institut für Wirtschaftsforschung
DSTI	Directorate for Science, Technology and Industry (OECD)
EFI	Expert Commission for Research and Innovation
EPO	European Patent Office
ESA	European Space Agency
Eurostat	Statistical Office of the European Communities
EU	European Union
GDP	Gross domestic product
GEM	Global Entrepreneurship Monitor
GmbH	Limited liability company
IAB	Institut für Arbeitsmarkt- und Berufsforschung
IC	Information and communication
ICT	Information and communications technology
INSEE	Institut Nationale de la Statistique et des Études Économiques
IT	Information technology
MERIT	Maastricht Economic Research Institute for Innovation and Technology
NIW	Niedersächsisches Institut für Wirtschaftsforschung
OECD	Organisation for Economic Cooperation and Development
PISA	Programme for International Student Assessment
PPP	Purchasing power parity
R&D	Research and development
R&I	Research and innovation
RCA	Revealed comparative advantage
SBA	Small Business Administration
SCI	Science Citation Index
SME	Small and medium-sized enterprises
StBA	Federal Statistics Office
WIPO	World Intellectual Property Organization
ZEW	Zentrum für Europäische Wirtschaftsforschung

LIST OF ABBREVIATIONS OF SINGLE STATES

BE	Belgium
CH	Switzerland
DE	Germany
DK	Denmark
ES	Spain
FI	Finland
FR	France
GB	Great Britain
IT	Italy
JP	Japan
KR	Korea
NL	Netherlands
NO	Norway
PT	Portugal
US	United States of America

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ACKNOWLEDGEMENTS

The Expert Commission for Research and Innovation is grateful to all those who have contributed to this report:

Prof. Knut Blind	EFI Coordination Office
Jeanette Braun	Fraunhofer Institut für System- und Innovationsforschung (ISI)
Dr. Reiner Braun	KfW-Stiftungslehrstuhl für Entrepreneurial Finance, TUM Business School, Technische Universität München (TUM)
Marcel Helbig	Wissenschaftszentrum Berlin für Sozialforschung (WZB)
Katja Hillmann	EFI Coordination Office
Dr. Karin Hoisl	INNO-tec – Institut für Innovationsforschung, Technologiemanagement und Entrepreneurship an der Ludwig-Maximilians-Universität München
Bernd Müller	Fraunhofer Institut für System- und Innovationsforschung (ISI)
Christiane Scholz	Wissenschaftszentrum Berlin für Sozialforschung (WZB)
Dr. Ulrich Schmoch	Fraunhofer Institut für System- und Innovationsforschung (ISI), EFI Coordination Office
Dr. Gero Stenke	EFI Coordination Office
Dr. Torben Schubert	Institut für Wirtschaftspolitik und Wirtschaftsforschung an der Universität Karlsruhe, Fraunhofer Institut für System und Innovationsforschung (ISI)
Birgit Trogisch	EFI Coordination Office
Sabine Wurst	Fraunhofer Institut für System- und Innovationsforschung (ISI)

And also all those who have contributed to the studies on the German innovation system.

This report is based on studies commissioned by the Expert Commission for Research and Innovation and carried out by the following institutions:

– Niedersächsisches Institut für Wirtschaftsforschung (NIW), Hannover
– Fraunhofer Institut für System- und Innovationsforschung (ISI), Karlsruhe
– Deutsches Institut für Wirtschaftsforschung (DIW), Berlin
– Zentrum für Europäische Wirtschaftsforschung (ZEW), Mannheim
– Bundesinstitut für Berufsbildung (BIBB), Bonn
– Stifterverband für die Deutsche Wissenschaft, Essen
– Hochschul-Informations-System GmbH (HIS), Hannover
– Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI), Essen

The studies are published by the Commission of Experts for Research and Innovation (EFI) in the series 'Studien zum deutschen Innovationssystem' which can be accessed at www.e-fi.de.

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1-2008 Belitz, H.; Gehrke, B.; Grenzmann, Ch.; Legler, H.; Leidmann, M. (contributor) (2008): Forschungs- und Entwicklungsaktivitäten im internationalen Vergleich, Berlin.
2-2008 Belitz, H.; Clemens, M.; Gornig, M.; (2008): Wirtschaftsstrukturen und Produktivität im internationalen Vergleich, Berlin.
3-2008 Döhrn, R.; Engel, D.; Stiebale, J. (2008): Außenhandel und ausländische Direktinvestitionen deutscher Unternehmen, Berlin.
4-2008 Rammer, Ch.; Weißenfeld, B. (2008): Innovationsverhalten der Unternehmen in Deutschland – Aktuelle Entwicklungen und ein internationaler Vergleich, Berlin.
5-2008 Rammer, Ch. (2008): Unternehmensdynamik in den forschungs- und wissensintensiven Wirtschaftszweigen in Deutschland. Zur Entwicklung von Gründungen und Schließungen im internationalen Vergleich 1995-2006, Berlin.
6-2008 Gauch, S.; Hinze, S.; Tang, L. (2008): Leistungsfähigkeit und Strukturen der Wissenschaft im internationalen Vergleich 2007, Berlin.
7-2008 Frietsch, R; Blind, K. (2008): Patente im internationalen Vergleich – Strukturen und deren Veränderung, Berlin.
8-2008 Ebcinoglu, F.; Frietsch, R.; Gehrke, B.; Heine, Ch.; Helmrich, R.; Kerst, Ch.; Leszczensky, M.; Schaeper, H.; Schoengen; K. (2008): Bildung und Qualifikation als Grundlage der technologischen Leistungsfähigkeit Deutschlands. Bericht des Konsortiums 'Bildungsindikatoren und technologische Leistungsfähigkeit', Berlin.
9-2008 Gehrke, B.; Legler, H.; Leidmann, M. (Mitarbeit) (2008): Forschungs- und wissensintensive Wirtschaftszweige in Deutschland: Produktion, Wertschöpfung, Beschäftigung und Qualifikationserfordernisse, Berlin.

END NOTES

1 In 2006, 69 per cent of all R&D expenditure came from companies. Cf. Stifterverband Wissenschaftsstatistik (2008).
2 Stifterverband für die Deutsche Wissenschaft (2008).
3 BMBF (2007a), p. 37.
4 Cf. in OECD (2007d) Figure 3.7.2 (environmental technologies), 3.5.2 (wind energy), 3.6.2 (fuel cells), 3.2.2 (nanotechnology).
5 The concept 'Schumpeter Goods', named after the pioneer of innovation research Josef Schumpeter, was proposed by Giersch, H. (1979, p. 632 f.) and also used by Klodt, H. (1990) for so-called technology-intensive branches of industry, which he called Schumpeter Industries.
6 Cf. Frietsch, R.; Legler, H. (2007).
7 Cf. Aschhoff, B. et al. (2008).
8 According to SV Wissenschaftsstatistik, 298 072, 298 549, 304 503, and 312 126 employees (full-time equivalents) were active in R&D in the years 2003 to 2006, respectively. Estimating the personnel needed for an R&D intensity of three per cent on the basis of the R&D intensities and personnel figures for these years, a gap of some 63 000 personnel is obtained relative to 2006. Since the GDP can be expected to grow by approx. Ten per cent by 2010, the overall estimated result is some 70 000 employees.
9 Cf. Deutscher Sparkassen- und Giroverband (2007).
10 Cf. Rammer, C. (2007).
11 Cf. EVCA (2006).
12 Cf. Achleitner, A-K. et al. (2006).
13 Cf. Jahresgutachten des Sachverständigenrat zur Begutachtung des gesamtwirtschaftlichen Entwicklung 2006/07, Items 409-455.
14 Cf. Jahresgutachten des Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung 2005/06, Item 421.
15 Cf. Press release, 18 July 2007, BMWi: 'Wissenschaftlicher Beirat legt Brief zum Thema "Gesetzentwurf Wagniskapitalbeteiligung (WKBG) und Unternehmensbeteiligungsgesellschaften (UBGG)" vor.'
16 Cf. Ernst & Young (2007), p. 81.
17 Cf. Haagen et al. (2007), p. 32.
18 Cf. Kaserer, C.; Achleitner, A-K.; von Einem, C.; Schiereck, D. (2007). The transactions were registered by Venture Source, a private equity database and subsidiary of Dow Jones & Company.
19 Cf. Fryges, H., S. Gottschalk, G. Licht and K. Müller (2007).
20 For Business Angels, the MoRaKG Act envisages that the tax-free amount allowed in Section 17.3 Income Tax Act for profits from the sale of company shares which constitute more one per cent of the nominal capital is increased to 20 000 euros. This does not address the needs of business angels.
21 Cf. Achleitner, A. K.; Kaserer, C. (2007).
22 Cf. BMBF (2007a), p. 68f.
23 More precisely the R&D-user costs. The calculations and results are presented in Warda, J. (2006).
24 Cf. HM Treasury (2005), http://www.hmrc.gov.uk/consult_new/rd-taxcredit.pdf (retrieved 6 February 2008). Companies without tax arrears can receive 24p for every £1 of R&D expenditure (Chapter 3.16).
25 Cf. Griffith, R. (2000), http://www.hm-treasury.gov.uk/media/5/9/255.pdf (retrieved 6 February 2007). Cf. Parsons and Philipps (2007).
26 The European Commission has recommended implementing measures to provide tax incentives for the promotion of R&D. Cf. European Commission (2006), http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0728:FIN:EN:PDF (retrieved: 11 May 2008).
27 Cf. Belitz, H. et al. (2008a).
28 Cf. Hujer, R.; Radic, D. (2002), p. 489.

29 Cf. MERIT and Joint Research Centre (Institute for the Protection and Security of the Citizen) of the European Commission (2007).

30 Cf. BDI and Deutsche Telekom Foundation (2007).

31 Cf. BMBF (2007a).

32 Even if children with migration backgrounds are not included, Germany has a very high proportion of school students who are poor in skills.

33 The 'Institute für Qualitätssicherung in der Schule' allows comparisons of schools between laender. The introduction of quality measurements in British schools, coupled with choice and budgetary effects on the schools has led to considerable improvements and improved competence levels for all British schools. There has been no evidence of a division emerging as was feared, cf. Glennerster, H. (2001).

34 The introduction of the new Bachelor's degree course could lead to improvements. We will be observing this closely and will return to it in future reports.

35 Based on the projections of ZEW for three options: 1) The overall rate of employment falls by 2.5 per cent until 2014; 2) Steady rate of employment; 3) An increase of 2.5 per cent. Knowledge intensification is also assumed to continue. The calculations also considered the replacements for retirees and the numbers and structure of the available unemployed, as well as available university graduates. Cf. BMBF (2007a), p.119.

36 In 2006, 28.9 per cent of females in the cohort qualified for university entrance, against 21.6 per cent of males. Only 5.9 per cent of females left school without any qualification against 9.7 per cent of males. (Source: Federal Office of Statistics, our calculations).

37 Cf. Bertelsmann Stiftung (2007).

38 No less that nine separate steps are involved in the procedure, and in particular SMEs find they simply do not have the time or personnel it would take to work through this. Cf. Sachverständigenrat für Zuwanderung und Integration (2004), p. 131f.

39 Cf. Böhmer, M. (2007).

40 Cf. Bos, W. et al. (2004); Cf. Ditton, H. et al. (2005).

41 Cf. Belitz, H. et al. (2008b).

42 Cf. Belitz, H. et al. (2008b).

43 Cf. IAB (2007b).

44 Cf. Lehmann, R. H. et al. (1997); Bos, W. et al. (2003).

45 Cf. Boudon, R. (1974).

46 Cf. www.bmbf.de/pub/qualifizierungsinitiative_breg.pdf (retrieved January 2008).

47 Data on educational expenditure is taken from the annual OECD reports 'Education at a Glance', for which values are standardised, offering comparability, validity and reliability for the 30 OECD countries since the start of the 1990s. Cf. Nikolai, R. (2007).

48 Cf. Grupp, H. et al. (2004).

49 Bund-Länder-Kommission: 'Steigerung des Anteils der R&D-Ausgaben am nationalen Bruttoinlandsproduckt (BIP) bis 2010 als Teilziel der Lissabon Strategie', 27 November 2007.

50 Cf. Grupp, H.; Breitschopf, B. (2006).

51 Cf. Fier, A. (2002).

52 Cf. BMBF (2006).

53 Cf. Licht, G. et al. (2007).

54 Cf. ibid.

55 Cf. BMBF (2007c), See also the reply by the ministry to the written query No. 10/251 - 254 from the German Bundestag.

56 The report 'Forschung und Innovation in Deutschland 2007 – im Spiegel der Statistik', Cf. BMBF (2007d) does not include any such summary. This is surprising because the ministry is responsible for the relevant reports by the federal government and also in other places provides appropriate presentations of the R&D expenditures of other departments.

57 Cf. BMBF (2007a), p. 25.

58 Cf. BMBF (2005), p. 52 f.

59 Cf. BMBF (2007e), Eckpunkte für ein integriertes Energie- und Klimaprogramm (Meseburg 8/2007), Masterplan Umwelt (BMU and BMBF, in preparation) and Roadmap Umwelttechnologie 2020 (in preparation). The latter is a research project carried out by the Research Centre Karlsruhe for the German government. It is intended to show possible technology developments for environmental technology. Promotion announcements by BMBF on Hightech Strategy Environmental Technologies include 'Rohstoffintensive Produktionsprozesse' (12/2007) and 'KMU – Innovativ: Ressourcen- und Energieeffizienz' (09/2007).

60 Cf. Wissenschaftlicher Beirat (2004), http://www.sfv.de/lokal/mails/wvf/zukunftd.htm (retrieved 6.02.2008).

61 Energy research topics include: Federal Ministry of Education and Research (BMBF): Basic and applied technology development in the fields of biomass, photovoltaics, wind energy, geothermics, storage technologies (power and heat), hydrogen technology, batteries, nuclear fusion, energy efficiency in buildings, energy-efficient cities, transport technologies, nuclear safety research, (basic research in most of these areas),

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU): Photovoltaics, thermal solar energy in buildings, solar-thermal power stations, storage technologies (electricity and heat), wind energy, geothermics, hydro-electric power, and wave power,

Federal Ministry of Economics and Technology (BMWi): Coal + lignite power station technologies, hydrogen technology, reactor safety research, storage of radioactive waste, district heating, storage technologies (power and heat), heat storage, energy-optimised construction, energy-efficient cities, geothermics, BMWi is responsible for the coordination of the energy policy of the German federal government,

Federal Ministry of Transport, Building and Urban Affairs (BMVBS): Energy efficiency in building, urban development, energy efficient transport systems, hydrogen technology,

Federal Ministry of Food and Agriculture and Consumer Protection (BMELV): The use of biomass, including biofuels,

Federal Ministry for Economic Cooperation and Development (BMZ): Use of energy technologies in developing and threshold countries,

Federal Ministry of Finance (BMF): Institutionalisation of a hydrogen technology activity between BMVBS, BMBF, BMWi and in part BMU.

62 Cf. Beise, M. et al. (2002).

63 Cf. BMBF (2007a), p. 44.

64 After Murmann, J. P. (2003), and Landau, R.; Rosenberg, N. (1992).

65 Cf. ibid, p. 34, Table 3-2.

66 Some established companies have managed to switch to a completely new line of business in the high-technology sector; for example Mannesmann successfully established itself in the mobile phone sector. But such cases are rare. New actors tend to start as spin-offs from other companies, universities or research institutions.

67 Cf. Sternberg, R. et al. (2007).

68 Cf. BMBF (2007a), p. 50, Figure 3.16.

69 Cf. Eidenmüller, H. (2007).

70 For instructive examples see Teece, D. (1986).

71 Cf. Hauschildt, J. (1997), p. 128f.; Zwick, T. (2002, 2003).

72 Cf. Freeman, J. et al. (1983).

73 After Döhrn and Engel (2008), Belitz et al. (2008a) and Gehrke et al. (2008).

74 The foreign trade figures for aeronautics and astronautics are complicated by the fact that they mostly involve internal deliveries by Airbus.

75 In this report, a definition of the RCA is used where the relation of exports to imports of a country in a specific group of products is referred to this relation for the total economy of the country considered.

76 The following text is based on Belitz et al. (2008a).

77 BAS = Beitrag zum Außenhandelssaldo (Contribution to the foreign trade balance).
78 More details can be found in section D 3–2 were the current growth of newly industrialised countries is extensively discussed.
79 Drawing on Belitz, H. et al. (2008a), Further information from Belitz et al. (2008b), Döhrn and Engel (2008), Frietsch (2008), Gauch et al. (2008), Gehrke et al. (2008).
80 The Amadeus European business database contains information about 10 million companies from 41 European countries: https://amadeus.bvdep.com.
81 For comparison: 18 per cent of companies with at least 100 employees.
82 Data on the gross national product of countries are usually compared on the basis of US dollars. These analyses include the effect that the purchasing power of one US dollar is different by countries leading to the calculation of dollars in purchasing power parities (PPP dollars).
83 The declining trend is confirmed by a current report of the Kreditanstalt fuer Wiederaufbau. Other investigations see a stable or slightly rising tendency, but they are either using a less strict R&D definition than the Frascati Standard, or the question about R&D is interpreted less strictly due to the use in another context. See Legler et al. (2006) for further details.
84 Cf. Fier and Czarnitzki (2004) and Fier and Eckert (2002).
85 The text here is based on Aschhoff et al. (2008).
86 Cf. Rammer und Weissenfeld (2008). The innovator rate is defined as the proportion of the companies with innovations among all companies with more than five employees. The figures for 2005 and 2006 are provisional. Values for the services sector have only been available since 1996. Values for other services before 2000 are not comparable with those for the following years and are therefore not documented. All data are projected on the basis of the respective German basic population of enterprises.
87 WIPO applications under the so-called Patent Cooperation Treaty (PCT). The text here draws on Frietsch, R. (2008).
88 Cf. Rammer and Weissenfeld (2008). Provisional values. All data are projected on the basis of the respective German basic population of enterprises.
89 The following text is based on Rammer. (2008).
90 For calculating the RPA index (Revealed Patent Advantage), the share of a country as to a specific field is referred to the share of this field within the worldwide patent applications. The mathematical formulation is analogue to that of the RCA for foreign trade.
91 The following text is based in part on Ebcinoglu, Frietsch, and Gehrke (2008).
92 People with post-secondary non-tertiary education.
93 Cf. BMBF (2007a).
94 Cf. Bonin, H. et al. (2007).
95 Cf. Statistisches Bundesamt (2007b).
96 Cf. Heine et al. (2006).
97 People with post-secondary non-tertiary education.
98 Cf. Trolsch (2007).
99 Estimates by BIBB on the basis of data of the Federal Office of Statistics and the Conference of Ministers of Education and Cultural Affairs (KMK).
100 Cf. the detailed definition in Gauch et al. (2008).

ISBN 978-3-00-025547-2