GERMANY'S TECHNOLOGICAL COMPETITIVENESS
Summary 1999

A report on behalf of the Federal Ministry for Education and Research

Submitted by

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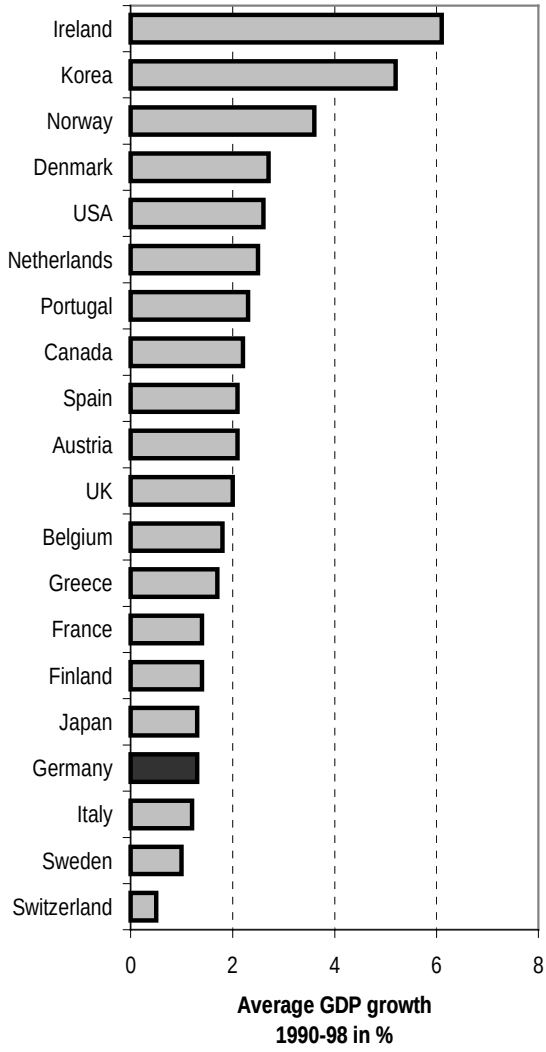
Mannheim, January 2000

Growth and investment weakness in Germany in the 1990s

The world-wide economic structural change is characterised by a progressive "knowledge intensification." In the long-run, the knowledge-based technical progress is an engine of growth and prosperity of societies. To what extent societies profit from worldwide technological progress, depends essentially on their technological performances and thus on the quality of their innovation systems.

Economic Growth in OECD countries in 1990s



If one examines the growth rates of gross domestic product in the nineties, some doubts are raised of whether the German innovation system was able to meet the challenges of the global knowledge economy. In a ranking of the twenty largest industrial nations in terms of overall economic growth, Germany came fourth last, well behind the United States, but also behind France, Denmark and Belgium.

Germany **still occupies an excellent position** in the international technological race: Germany has a large knowledge base and belongs to the countries with the highest R&D-capital stock. It also is the world's most fruitful source of world market-relevant patents per capita among the large industrialized countries. On average, German enterprises are highly productive and show a high potential for product and process innovations.

However, concerns exist regarding the **lack of dynamics**. Investments in the future, important to maintain the current position, fall short of long term needs in the nineties. The recent stimulation of R&D spendings, of equipment and of patent activities is limited in the international comparison. In the ranking of the countries with the highest investments in the future, Germany has fallen behind.

In order not to lose further ground, profound structural reforms are necessary, in order to enable the German economy to better take advantage of opportunities created by the global knowledge economy and unleash the soustainable economic dynamics to create jobs and fight unemployment. The German innovation system has a high potential to profit from up-coming trends and opportunities in the marketplace. It is crucial that these abilities are used with resolution, because in the "new economy," the speed and the flexibility to meet new challenges are paramount.

Traditionally, the **strength of the German economy** lies in the fast and far reaching diffusion of new technologies. But as innovation cycles become shorter especially this strength is called into question. Additionally, in many industries new competitors from developing countries, particularly from Southeast Asia, are

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endangering the positions of German enterprises. Technologically, these competitors can keep up and lead in the traditional German sales markets through sharp price competition. A high-wage country such as Germany cannot compete on this basis and must compete with technological sophisticated products and processes.

The German economy has its **core competencies** in developing complex innovations along known trajectories, such as automobile manufacturing and mechanical engineering. However, it cannot rest on its technological merits of the past. The German economy find it hard to enter fundamentally new technological trajectories like information and communication technology or biotechnology. Here changes are necessary. It is necessary that Germany not only keeps pace with other leading economies but also establishes technological leadership in some new technologies.

There are sights that the **immediate future** will be dominated by positive developments. The number of the applications for world market-relevant patents has risen sharply and the number of innovative enterprises is increasing, as is the productivity of the economy , the sales with new products and the exports of R&D-intensive goods. Last year's experience shows, however, that even a small, unexpected economic downturn can change the picture decisively.

In the **medium-term**, and even more so in the **long-term future**, the German innovation system displays significant shortcomings. Thus despite the recent rise in expenditures for research and development ground is being lost by international comparison. Also, with regard to the investments and expenditures for education and training, relative to GDP, Germany ranked below OECD average.

The report on Germany's technological competitiveness is co-authored by Dr. Georg Licht (ZEW), Jürgen Egeln (ZEW) und Dr. Harald Legler (NIW). The project was coordinated by ZEW. Dr. Harald Legler (NIW) chaired the working group on competitiveness indicators. This working group comprises researchers from Deutsches Institut für Wirtschaftsforschung (DIW, Berlin), the Fraunhofer-Institut Systemtechnik und Innovationsforschung (ISI, Karlsruhe), the Niedersächsisches Institut für Wirtschaftsforschung (NIW, Hannover), the Wissenschaftsstatistik im Stifterverband für die Deutsche Wissenschaft GmbH (Essen) and the Zentrum für Europäische Wirtschaftsforschung (ZEW, Mannheim).
The full report is available from the internet: www.zew.de/tl99.

Challenges for Research, Innovation und Education Policy

A good track record of innovation does not mean that the effort to adapt the innovation system to meet new requirements and challenges can be diminished. The German innovation system should orientate itself more strongly towards genuine technological innovations without neglecting the traditional strengths in the rapid adoption and diffusion of technological innovations along well established trajectories. Such reorientation will only be successful in medium and long run when policy changes take place.

First of all, economic policies have to pursue consistent approaches. Therefore, it should be emphasized that innovation policy should play an important cross-sectional co-ordinating role to stimulate a consistent policy framework. The simultaneity of policy towards dynamic technological change and preservation of the existing economic structure may send contradictory signals thereby increasing the uncertainty of future policy action towards the restructuring of the German economy. Regarding the necessary changes of the German innovation system the policy must orientate itself towards:

- the financial and structural improvements through education, training, and life-long learning;
- the improvement of the conditions for industrial R&D and innovation as well as wide-ranging reforms of the public R&D system;
- improvement of the framework conditions.

Education and Training

The expenditures on education are - even when taking into account their recent expansion too - small compared to the increasing importance of knowledge and education in the new economy.

But cash is not the only answer. Up-to-date flexible structures in all fields of education and training are the substantial prerequisites for the competitiveness in new technology based industries. Universities play a key role here. Hence, their structural reform has to take place without any delay. Important items of such reform are:

- stronger competition between universities for the best quality of education,
- incentives for students for efficient and practice-oriented study paths,
- adaption to internationally-recognized degree standards and university career paths,
- a flexible system of courses to enable different specialization degrees and content-wise (also interdisciplinary) combinations.

In addition, vocational education should be more flexible and enable different occupational education structures, as well as substantially faster adjustments of the training content to new technological requirements.

Industrial R&D and innovation

In an international comparison, the German economy has dropped back in terms of the R&D-intensity in recent years. Therefore, the conditions for industrial R&D should be improved. Since most substantial incentives for R&D are challenges found in the market, it is crucial to pay attention to market signals. Competition policy is innovation policy: the more open and liberalized a market is, the easier it is to uncover business opportunities. The telecommunications market proves this impressively.

An important step towards an improvement of the environment for industrial R&D can be seen in the proposed tax reform. The improvements of the scope for internal financing will foster the R&D intensification of the economy. An R&D tax credit granted already in many countries could additionally stimulate the R&D inclination of the economy, especially for 'Mittelstand' companies.

Public science and industrial research

Publicly-financed science and research do not justify themselves alone or by their independent targets. The system also has to be assessed according to its impact on the economy. All public research have to devote more attention to this criterion than they have done so far. In order to accomplish this, changes in their technological scope, competition between institutions as well as regular evaluations of the quality and emphasis of the research are necessary.

It should be an eminent task for publicly-employed scientists to strive actively for the transfer of research results to the private economy. The direct transfer linking science and industry appears to be more appropriate than the current system of institutionalized transfers and managing agents. A prerequisite for this is reform of the public service employment law and the budgetary law of the public research institutions, which appear less and less suited in their present form for scientific institutions.

Obstacles for innovative start-ups

New enterprises often take the lead in diffusing new technologies. If they are successful they grow fast; if they are unsuccessful, they cease operations just as fast. It is in this creative dynamics where large opportunities can be found. Therefore, an innovation-oriented economic policy must support self-employment and firm formation in new technology fields. Deregulation creates new markets and market niches for new enterprises and stimulates firm dynamics. Often, qualified specialists are not available to new enterprises. This applies particularly to young, fast growing technology start-ups. The mobility of experienced managers is small. In such cases, success-oriented remuneration models (like stock options) can play a role in reducing the expertise deficits and make the change more attractive for experienced managers. However, recent tax court decisions make stock options less attractive. Hence, there is some room for stimulating the use of stock options by reforming the tax laws.

Trends and Recent Developments

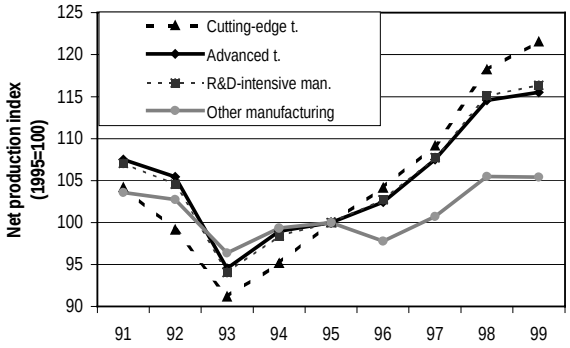
Currently the German economy is on a flat growth path. After the economic cooling in the first half of 1999, new momentum seems to be on the horizon. The projections are accordingly optimistic for the year 2000. The current economic developments are, however, important as they decide the momentum with which an economy recovers and also determine whether sufficient grounds exist to justify investments in future products and manufacturing processes. This momentum also substantially influences the future position on the world markets.

Structural shift towards R&D intensive industries

The R&D intensive industries performed better in the economic downturn than the non-R&D intensive industries. For 2000, the production growth in R&D-intensive industries is expected to be between 3 percent and 5 percent (1999: 1 percent). The non-R&D intensive industries, after a recording –0.5 percent growth in 1999, are expected to grow only between 2.5 percent and 3 percent.

Net production in manufacturing

1995 = 100



Cutting-edge technology outperformed **other R&D intensive industries**, where the price competition from countries with lower labor costs becomes increasingly apparent.

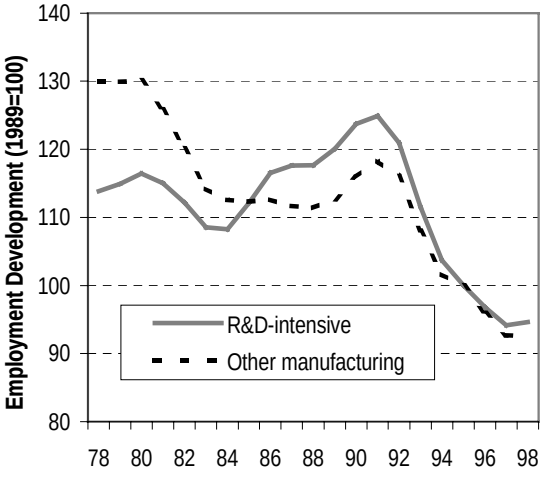
In average, the development in the **new Länder (NBL)** was clearly better in the 1990s than in the **old Länder (ABL)**. In the NBL during the period 1993-1998, the R&D intensive industries (NBL: 7.7 percent; ABL: 3.9 percent) grew faster than the non-R&D intensive industries (NBL: 5.4 percent; ABL: 1.1 percent). Cutting-edge technology shows above-average dynamics (NBL: 11.2 percent; ABL 4.9 percent). However, the share of the R&D-intensive industries to all industries is still small in the NBL.

The field of cutting-edge technology comprises goods with an average R&D intensity (R&D/sales) of 8.5 percent. The advanced technology covers goods (resp. industries) with an average R&D intensity between 3.5 and 8.5 percent. Together, both form the R&D intensive sectors of the economy.

Sluggish employment growth in R&D-intensive and knowledge-intensive industries

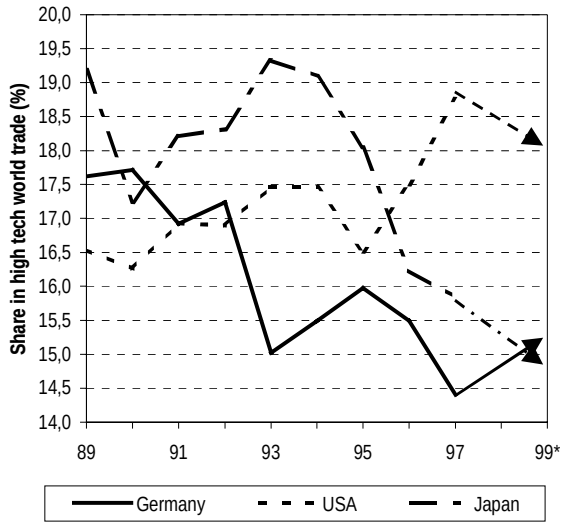
Production growth was too small to create additional workplaces in the economy. However, the **substantial reduction of the employment** in industry was stopped in 1999. The reduction of employment was strongest in cutting-edge technology during the nineties. However, it is only in cutting-edge industries where employment levels reach figures known from the seventies. Both advanced technology and the non-R&D intensive sectors show historical employment lows.

Employment development in manufacturing



Additional employment is generated in the **service sector**, where one can observe dynamics similar to those in other European countries. However, the substantial employment reduction of the former publicly-owned mail and railway companies after deregulation cloud the positive

Share in world trade with high-tech goods
1989-99



employment development in other knowledge-intensive services. This also explains the fact that knowledge-intensive services show smaller employment growth than the other services.

World trade position of R&D-intensive goods is improving continuously.

The recovery of the industry relies on increased exports. R&D intensive industrial goods are responsible for an increasing share of German exports. In the period 1994-1997, **the exports of R&D intensive goods** rose annually on average by 10 percent, while the exports of non-R&D-intensive goods rose only by 8 percent. In cutting-edge technology, growth was substantially higher. Similar patterns can also be seen for the new Länder, which have succeeded in increasing their exports tremendously in recent years. However, the export share of the new Länder is, with the exception of a few industries, still clearly below the level of the old Länder.

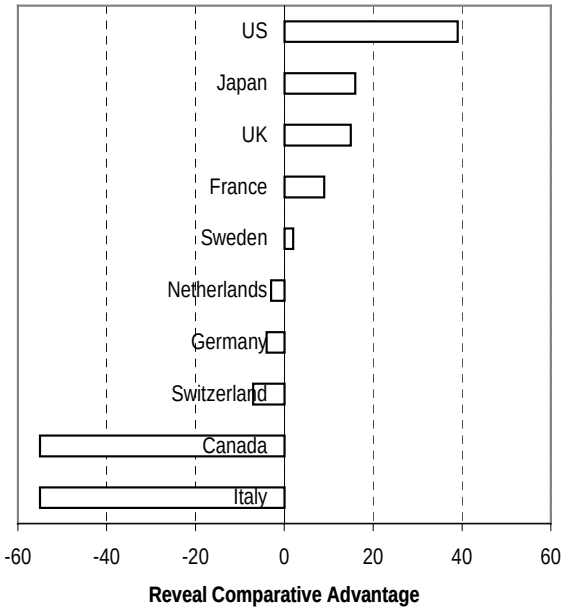
The R&D-intensive industries recorded barely half of their 1998 sales abroad. The new Länder, the export share of which already achieves 32 percent in R&D intensive industries, are still clearly below this all-German average. Even more, only 3.5 percent of the foreign sales of Germany's R&D intensive industries stem from the new Länder.

The **decrease in the world trade share** of German R&D intensive goods will probably be reversed in the near future. The United States are still the largest exporter of R&D intensive goods, followed by Germany and Japan. In terms of R&D-intensive imported goods, Germany ranks second behind the USA, which are responsible for a quarter of world imports of R&D intensive goods.

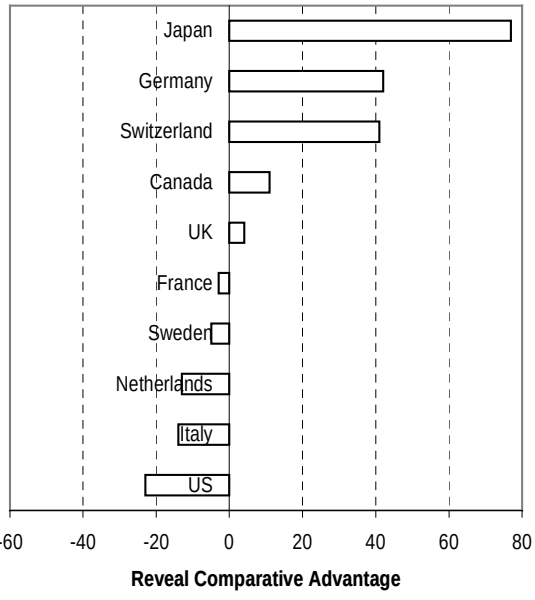
Still, Germany is particularly strong in goods that require above-average R&D efforts ("advanced technology"). However, Germany plays less of a role where extremely high R&D ex-

Trade specialisation of leading economies 1997

Cutting edge technology



Advanced technology



penditures are necessary ("cutting edge"). This becomes particularly clear in comparison with the USA and Japan. Germany's trade deficits in cutting-edge technology are mainly due to the trade with the USA and Japan. In Europe Germany is, however, a leader in cutting-edge technology.

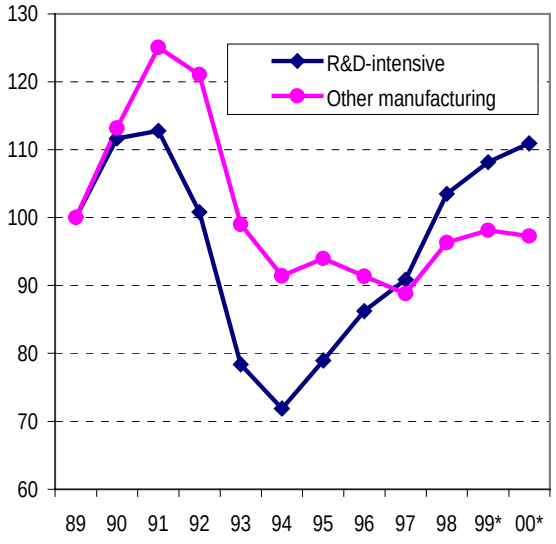
Recent improvements in the position of cutting-edge technology is primarily due to the upswing in telecommunications after industry deregulation. A **progressive erosion** of the advantages takes place in pharmaceutical goods. The advanced technology registers increasing foreign trade surpluses, particularly in the automobile industry.

Small dynamics in the development of production capacities

Since the middle of the 1990s, the growth of the **production capacities** of the economy have slowed down and appeared noticeably sluggish. This applies quite similary to the R&D-intensive and the non-R&D-intensive industries. Recently, the development in R&D intensive industries appears to be a bit more positively.

The **investments in equipment and material assets** within the R&D intensive field reached pre-recession levels for the first time in 1998.

Investment in equipment and structure



For the year 2000 a further, though smaller, rise is expected. In the non-R&D-intensive sectors, the investments are still clearly below their levels from the beginning of the 1990s. In 1999 and 2000 no investment growth is expected in this area.

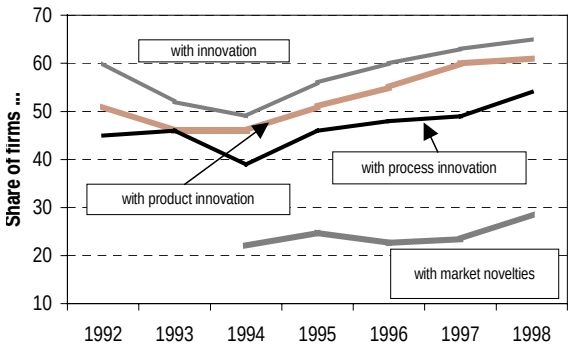
The entire increase in investments in the industry is almost completely based on the R&D-intensive area. This becomes particularly clear in the medium-term view with 90% of investment in manufacturing belonging to R&D intensive industries.

The comparatively high investment activity in the new Länder is declining a little. But the investment per employee is still above the level of the old Länder.

Innovation is common to an increasing number of firms

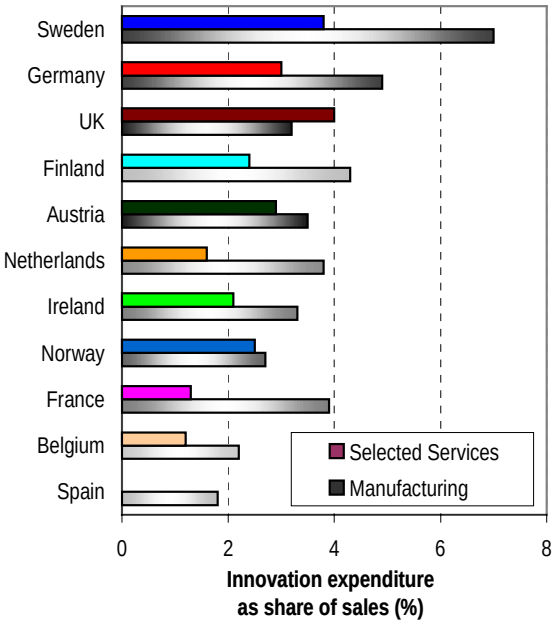
A growing proportion of enterprises develop innovations in industry and in knowledge-intensive service sectors. On one hand, the **rising proportion of innovative enterprises** is based on the fact that additional enterprises have tackled innovation. On the other hand, the rise is due to the fact that non innovative enterprises disappear from the market. Without innovation survival becomes more and more difficult in all industries.

Share of innovative firms by type of innovation



In addition, the expenditures of the enterprises for innovations show a pleasant rise in 1998. For 1999, however, no further increase in the innovation expenditures is expected. With regard to **innovation intensity** (innovation expenditures related to sales), Germany is ranked second in the EU. This is proof of the high innovation readiness of German industry and acknowledges the technological leadership position of Germany in Europe.

Innovation intensity in EU-member states 1996



The innovation intensity of the new Länder in industry and in the service sector is still situated scarcely above the innovation intensity in the old Länder. This is mainly due to high levels of investment in new products and processes.

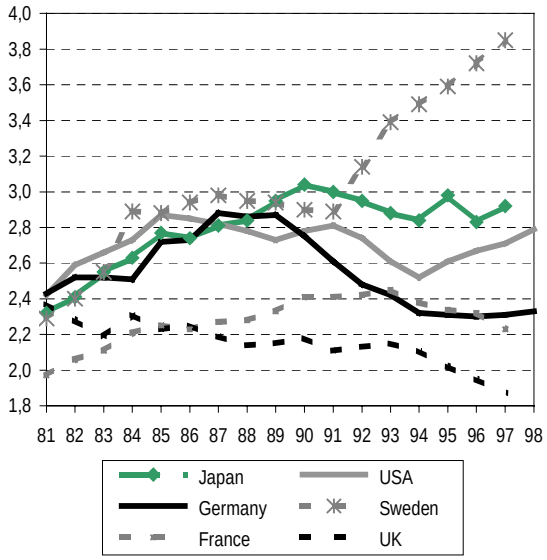
The sales of the enterprises with **product innovations** (i.e. with products that are new to the enterprise) rose clearly since 1994. Innovations now increasingly target new and improved products. This is also essential due to increasing international technological competition. Moreover, an increase was experienced in the turnover proportions with market novelties and the proportion of the enterprises that develop such market novelties.

However, the majority of product innovation is characterized by gradual advancements, product differentiations and imitations; but their high proportion hints to an accelerated diffusion of technical knowledge.

Despite rising R&D expenditures, Germany is losing ground internationally

The R&D expenditures of the economy as a whole were back on a growth path from 1995 onwards. The preliminary results for 1998 point to an increase in R&D expenditure of around 6.5 %. First, the preliminary data for 1999 suggest that the growth will be lower (approximately 4 percent). Additionally, the participation in R&D activities shows an increase among small and medium sized enterprises. The R&D intensity stabilized, after a strong collapse, in the second half of the 1990s and has been on a slow growth path in recent years. The R&D expenditures amount, as in the previous years, to approximately 2.3 percent of gross domestic product.

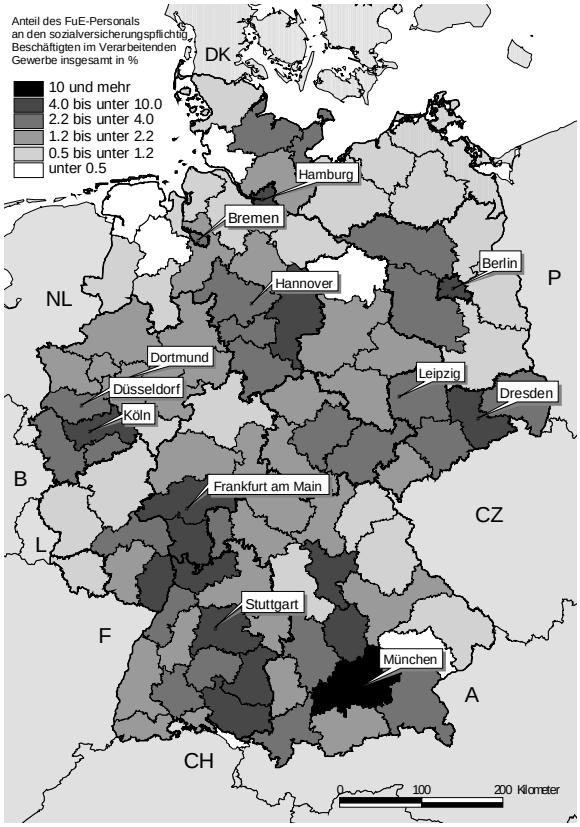
R&D intensity in selected OECD-countries 1981-1998



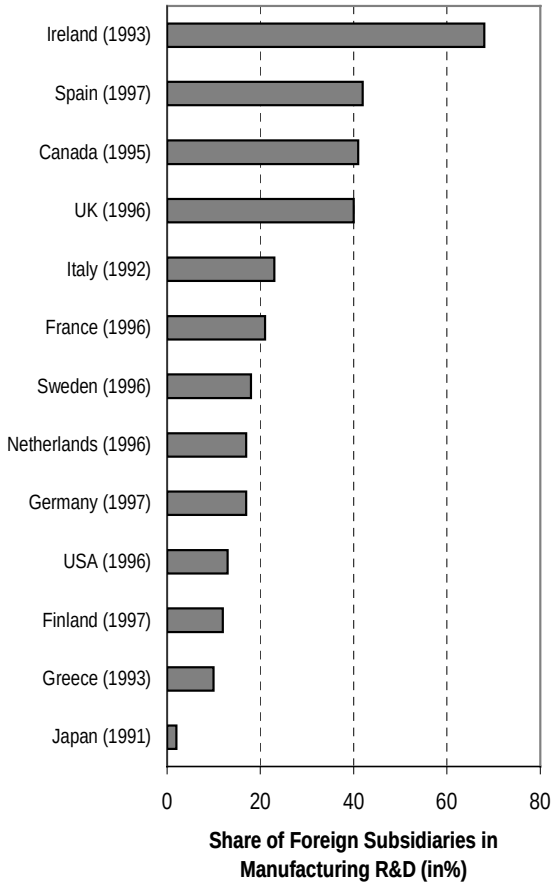
However, in an **international comparison**, the distance between Germany and the most R&D-intensive countries is growing. The enterprises of the USA and Japan, as well as those of some smaller European countries expanded their R&D expenditures substantially. Germany dropped back in the ranking of the most R&D-intensive countries and is now ranked seventh behind Sweden, Finland, Korea, the USA, Japan and Switzerland. The commitment to R&D within the automobile area has developed especially positively. In the long-term view, the pharmaceutical R&D in Germany has lost considerable importance. R&D activity has shifted towards automobile manufacturing and related industries.

Increasingly enterprises are having third parties to carry out their R&D activities. The external R&D expenditures of the enterprises rose much stronger in recent years than the internal R&D expenditures. In 1997, approximately 10 percent

Regional Distribution of R&D in German manufacturing



Share of R&D by subsidiaries of foreign MNE in total manufacturing R&D



of the R&D activities were "outsourced." The rise of the external R&D is primarily due to a stronger division of labour within the industry. The share of the external R&D expenditures held by scientific institutions decreased in the last few years; however, at the same time, their number of the R&D contracts grew.

The regional distribution of the economy's R&D capacities is substantially broader in Germany than in the other European countries. Nevertheless, various R&D regions have developed, which obtain top ranks among Europe's R&D-intensive regions (proportion of the R&D personnel of all persons employed of the processing trade). These multiple R&D centers in Germany can be regarded as advantageous with regard to quality of location and technology diffusion.

Increasing Internationalization in R&D

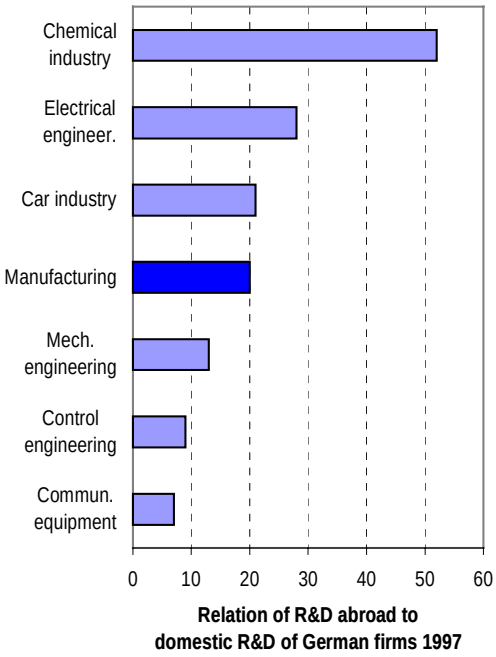
German enterprises have expanded their research capacities abroad. However, this is not, as frequently assumed, due to worse conditions at home. The major part of the internationalization of research and development is a by-product of the acquisition of companies abroad or of capacity extensions in existing operations. Taking advantage of the world market remains the priority target of internationally-active enterprises. The internationalization of research and development is in this context a by-product of transnational direct investments.

The **attractiveness of Germany** as a research centre is shown by the fact that the highest R&D intensity in foreign subsidiaries of US firms is in Germany. Also, after the UK, Germany is the most important centre of R&D in Europe for Japanese enterprises.

In a comparison of the **R&D shares of foreign enterprises** in terms of the entire domestic R&D expenditures, Germany just places ahead of the USA in the middle of the pack. Among the large industrialized countries, the UK clearly shows higher proportions of foreign R&D domestically, while Japan shows the smallest internationalization degree of the domestic R&D.

Chemical and pharmaceutical enterprises have been the pacesetters of the internationalization

Relation of foreign to domestic R&D in German manufacturing

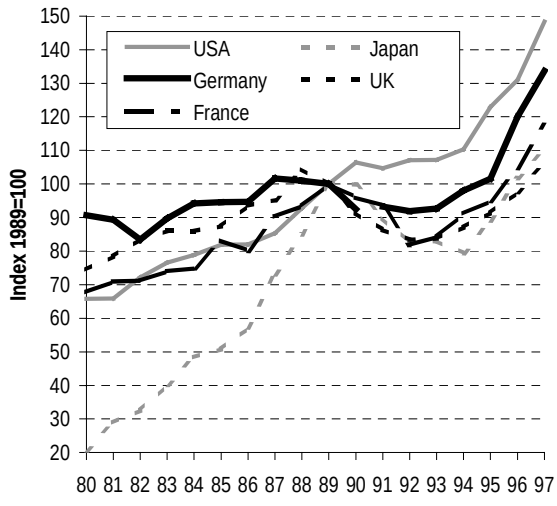


of the German industry of production and R&D. They spend more than half of their entire R&D expenditures on research and development abroad. Increasing proportions are also found in the automobile sector, which at the same time, however, also expanded its domestic R&D activities.

Steep increase in the number of the world market-relevant patents

The number of world market-relevant patents ("triad patents") rose strongly since 1994. Particularly in the most recent years of the observation period (1996, 1997), the number grew strongly. Since 1993, Germany has kept up the **growth speed of the USA** in terms of world market-relevant patents. However, the collapse in the patent activity at the beginning of the 1990s, which shows a sharp contrast to the USA, could not be reversed.

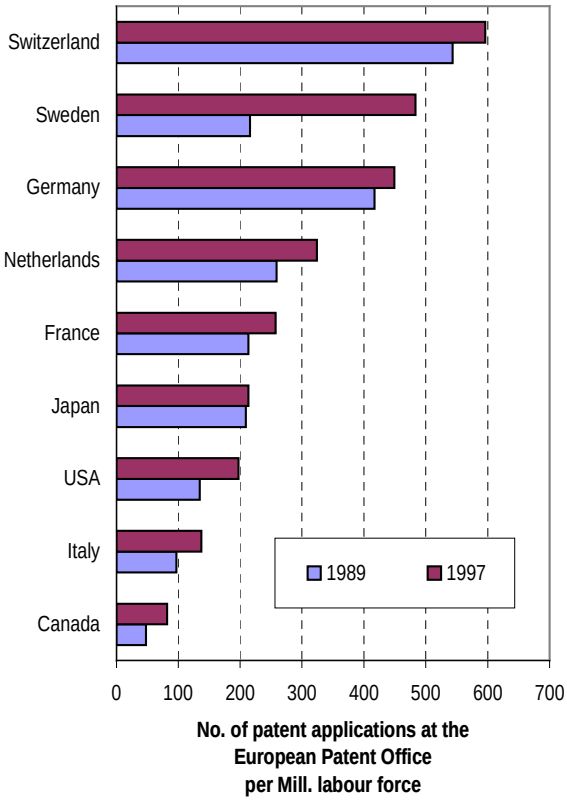
Development of the number of triad patents by country of origin



Nevertheless, Germany, together with Japan and the USA, still belongs to the most patent-intensive countries in the world (triad patents per capita or per employee). In 1997 the past record value dating back to 1989 were exceeded as measured by European patent applications.

Recently, a **shift of the patent structure toward research-intensive sectors** is occuring in Germany. The international technological division of labor is quite stable, with cutting-edge technology being dominated by the United States, Japan and, in recent times, Sweden. Germany, France, Switzerland, and Italy indicate a specialization on the advanced technology, usually in "traditional" industries such as automobiles and mechanical engineering.

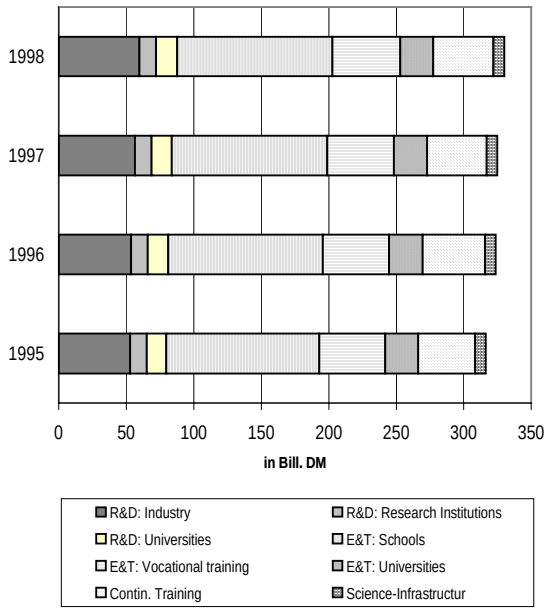
Patent intensity in leading inventor countries



Strong growth in world-wide patent applications altogether does not, however, only show up in the area of cutting-edge technology, but also in some fields of advanced technology, which has experienced increased patent activity. Therefore, Germany is also well represented in **fast growing technology fields**, such as automobile manufacturing, railroads and various branches of mechanical engineering. Relative to the high overall patent activity in Germany, patent activity is comparatively weak in other growth fields of international patenting, such as telecommunications and medical equipment.

Germany's patent specialization shows in nearly all fields of technology a **sharp contrast to US patenting**. Germany possesses above-average high patent proportions in environmental protection (polymer recycling, improvement of automobile recycling, biological water purification and domestic refuse handling), as well as within the area of aluminum and magnesium structures. Comparative disadvantages exist in the information technology and telecommunications (broadband communication and intelligent network technology, flat displays), as well as in biotechnology (DNS sequencing, genetically modified plants, vaccines from genetic production and recombinant medicines). Here the USA - as well as Japan in some subranges - plays the role of the technology leader.

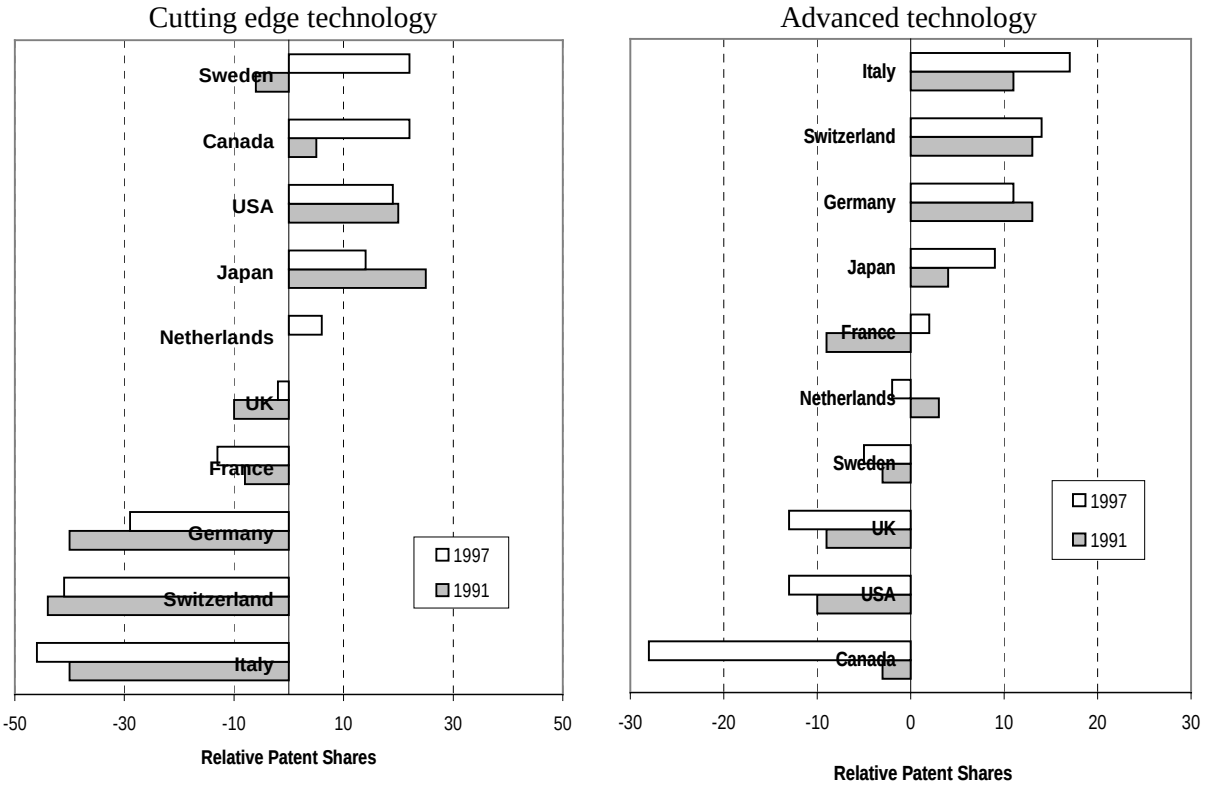
Spending on training, education and R&D in Germany



Insufficient investments in education and training

The overall economic outputs for building up and expanding the "knowledge base" (i.e. out-

Patent specialization of leading economies 1991 and 1997



puts of the industry for the dual vocational training system, further training and R&D, as well as the expenditure for education) can be estimated for Germany in 1998 at 330 billion DM, or 8.7 percent of the gross domestic product. The proportion of the domestic product shows a steady decrease in recent years. In the long-term, most industrialized countries clearly increased their investments in education and knowledge faster than the respective domestic product. In West Germany, the "education budget" sank clearly in relation to the domestic product. The proportion of expenditure for education and training on total public expenditures amounts to 10 percent, far below the OECD average of 12.5 percent. However, the industry in Germany also bears comparatively high loads in the context of the dual professional training.

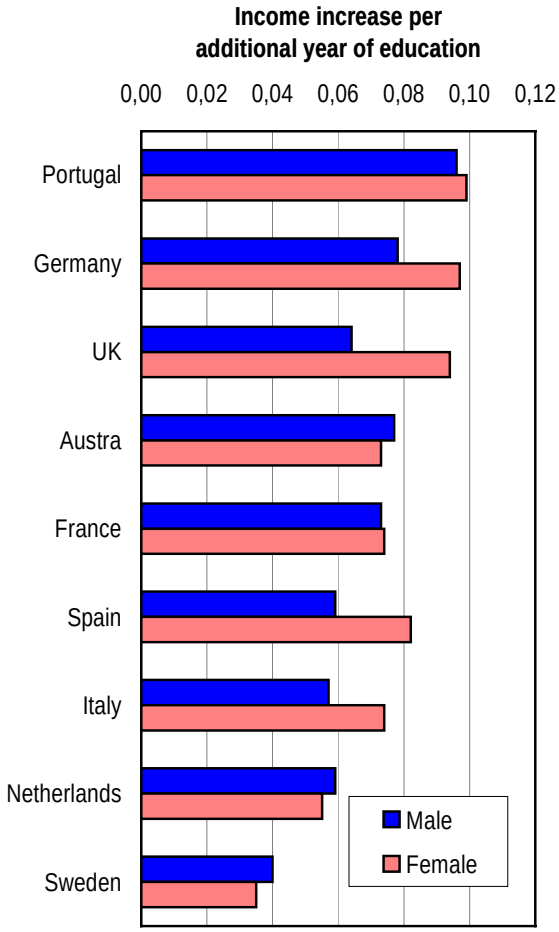
Increasing requirement of highly-qualified workforce

Innovations particularly favour the highly qualified labour in the job market. At the same time, many workplaces for less qualified workers are destroyed. On the job market, a constant change of the age structure which is also related to innovation takes place: Low qualified older employees are being replaced by qualified younger ones. More directly, whether young or old, whether less or highly qualified, education is now of a double value. Employees with higher qualification earn more (per year of the education about 8 percent) and the risk for university graduates and masters to become unemployed is only about one third as with employees who have not finished their education. Compared to the time necessary to reach a certain degree the highest return to education is gained by those holding a 'Meister' degree (vocational education master's degree) and a degree from universities of applied sciences.

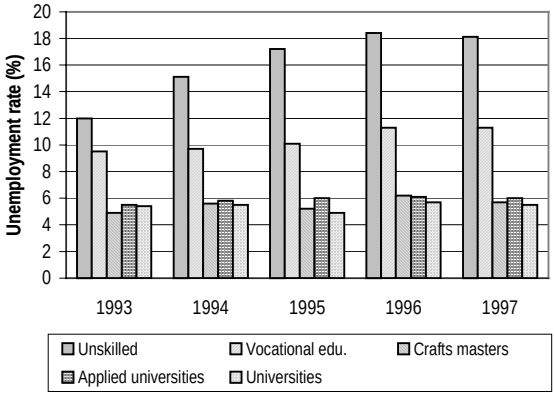
Labour market for highly-qualified workers

However, the risk of unemployment is not equivalent in all academic occupations. The risk is above-average with natural scientists and engineers, as well as with linguists and cultural scientists. The job market situation for older university graduates has clearly worsened (in particular for engineers). The reentrance into the workforce after a span of unemployment is particularly difficult for older university graduates; especially when new technologies have made old knowledge and old skills obsolete. Regular further training, in the sense of "lifelong learning" and "training on the job" must be adapted to further develop the abilities and talents to meet the challenges of technological innovation.

Return to education in Europe



Unemployment by skill groups in Germany



On the other side, the comparatively small number of scientists and engineers among the younger employees is precarious, particularly since this number will continue to decrease in the short-term. Bottlenecks are clearly in sight particularly in relatively new segments of the information and communication technology - a serious obstacle to innovation. It is exactly in this field where policy action is urgently needed. Given the time needed to 'produce' highly qualified IT-workers in a selective immigration policy seems to be a short-term solution to this problem.

R&D and innovation activities of SMEs

Small and medium-sized enterprises (SME) form the backbone of the innovative ability of the German economy. After a long phase of stagnation of their R&D expenditures SMEs have recently increased their expenditures on R&D. While small firms increasingly concentrate on cutting-edge technologies such as information and communication technology, as well as the measurement and control engineering, medium-sized and large enterprises set their R&D focus on "traditional" advanced technologies such as automobile engineering and mechanical engineering. Today, however, technology-oriented start-ups, as well as small and medium-sized enterprises take a leading role in commercialisation of new technologies and scientific results. In the new Länder SMEs play a central role in the innovation process. SME (enterprises with fewer than 500 persons employed) are responsible for 65 percent of the R&D expenditures in the NBL (1997). In the old Länder, it is only 16 percent.

The most important innovation obstacles are the lack of sufficient funds for innovation and, with increasing significance, the lack of skilled technical personnel. Also, time consuming administrative procedures and the regulatory framework contribute to delay or to cancelation of projects, despite some recent improvements within this area.

Start-ups in R&D intensive industries

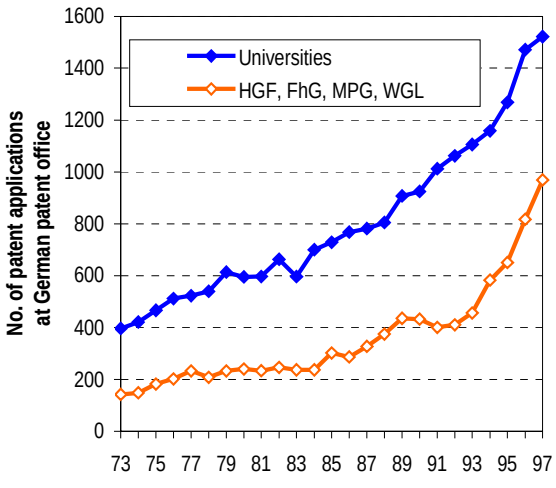
The number of the start-ups increased in Germany in the 1990s particularly in cutting-edge technology and in communication services (Internet and telecommunications). Parallel to this wave of start-ups, the market for venture capital expanded substantially, particularly in the segment of the start-up and early phase financing. Germany has clearly reduced what seemed only a few years ago an insurmountable gap to countries like the United States and the Netherlands. In Europe today, Germany is the largest market for early-phase enterprise financing. The financing volume at the participation capital market altogether grew from approximately 1.2 billion DM in the year 1995 on 5.8 billion DM in the year 1999.

With the establishment of new enterprises new workplaces also develop. In manufacturing, a start-up enterprise is on the average responsible for 4 to 5 new workplaces, with the knowledge-intensive service enterprises creating only 2 new workplaces. In terms of growth, start-ups in R&D-intensive industries or the service sector fare better than those in non-R&D-intensive industries. In the new Länder, the high start-up dynamics of the first few years diminished noticeably after the reunification. In advanced technologies, the negative trend continues. The cutting-edge technologies and telecommunications, however, develop just as positively as in the old Länder.

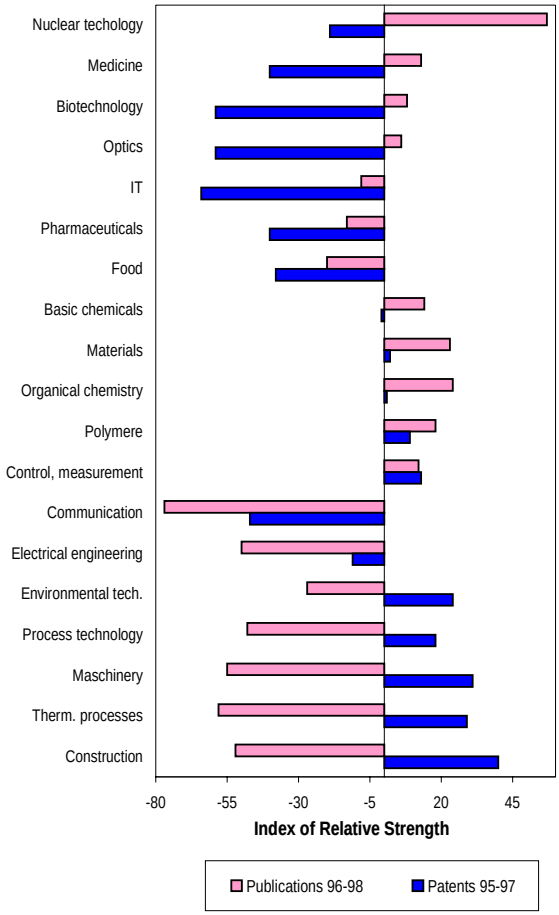
The efficiency of the science system

The relevance of scientific research for the technological development and the generation of new products and processes increased in the last

Patent application from German scientific institutions



Comparing the science and patent profiles of Germany



few decades on a broad front. The number of scientific publications, cited in patent applications, clearly increased in Germany, as in other countries. Germany has a rich research landscape. Aside from universities, important research institutions include the Max-Planck Society (MPG), the Helmholtz Society (HGF), the Fraunhofer Society and the Gottfried William Leibnitz Society (WGL).

Among the research institutions, the universities and the MPG indicate the largest publication intensity. The FhG ranks at the bottom of the list. In terms of the patent intensity, the exact opposite picture can be seen. The FhG leads this category. This corresponds to the mission and tasks of the individual research establishments.

Based on patent applications, the economic relevance of the research results of the public institutions has clearly increased. Particularly high rates of growth were achieved by the non-university institutions in the 1990s. The profile of the scientific specialization of the German research landscape and the technological specialisation of industry correspond to each other in many technology fields (e.g. measuring and automatic control, polymers and raw material chemistry). However, despite being a substantial scientific authority in some growth sectors, Germany is only relatively weakly represented in patent applications there (e.g. optics, data processing, medical technology).

Sustainable Development and Environmental innovations

In environmental technology Germany is well-placed on the world market. Germany is the second largest exporter of potential environmental protection goods behind the USA, which has strongly expanded its world trade share in the last years. The environmental technology is in line with Germany's traditional strength in the technological competition.

Accordingly, Germany is specialized in environmental patents (in particular noise protection, refuse disposal and treatment and purification of water). The specialization is less pronounced on environmentally relevant goods of the measuring and control engineering.

The dynamics with environmental relevant patent applications diminished in the first half of the 1990s and, measured by total patent development, rose only below average in recent years.

The legislation is one of the most important driving forces for environmental innovations. A stimulation of the innovation activity within the environmental area has positive results for both the environment, and technological performance.