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Rheinisch-Westfälisches Institut
für Wirtschaftsforschung

Employment Effects from Research and Innovation

Research project commissioned by the
Federal Ministry of Economics and Labor

Final report – Executive summary

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1. Background of the study

The research project „Employment Effects from Research and Innovation" addresses a current and thematically wide fanned-out problem field. Certainly, the analysis of the effect relationship between economic and technological development has been a subject of economic research for a long time, nevertheless some effect relationships are clarified only partly. Regarding this background the question is, to what extent can the economic location and technology location of Germany exist under the view of growth and employment, of substantial economic and political importance. Research and innovation and the development of new products, production procedures and organizational structures, which are a result of the research and innovation, play a central role. In connection with this, the following questions are to be answered:

- How do, compared to other countries, research and innovation have an effect on growth, productivity and employment at national economic, sectoral and single plant level?
- Which different employment effects result from product and process innovations?
- Are productivity and qualification of the employees changed by research and innovation and which consequences for employment arise from it?
- Is there a deficit with respect to invention or use of new advanced technologies in Germany?

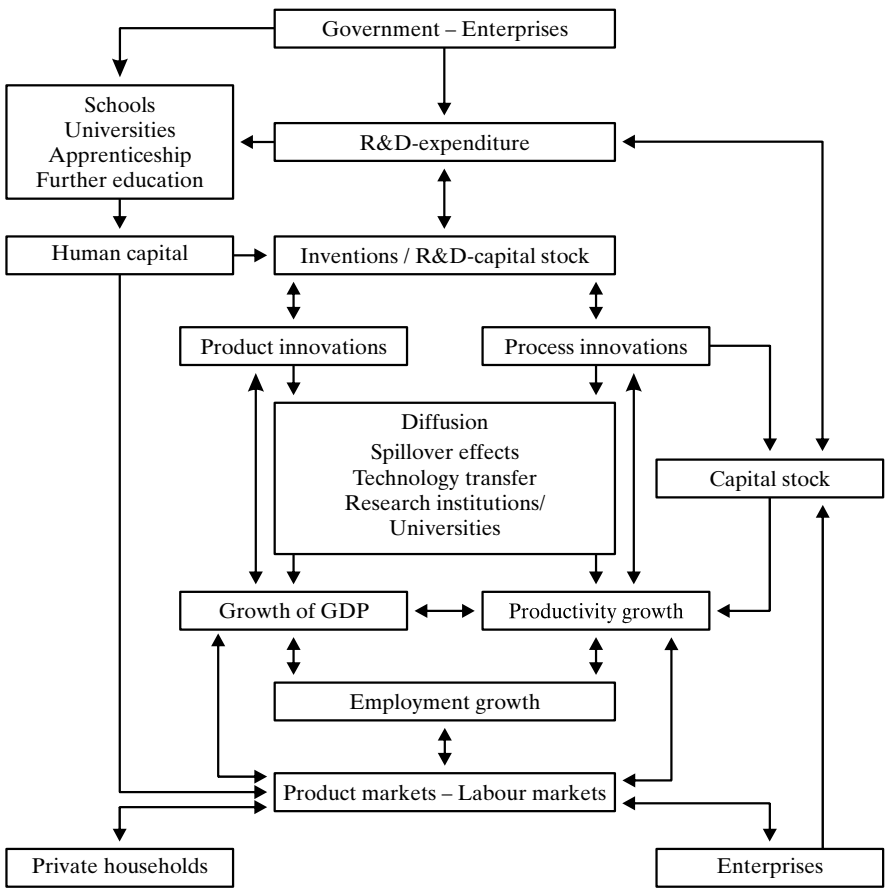
To answer these questions, a modular concept was developed, which makes, regarding the background of the current scientific level of knowledge, a differentiated analysis at different investigation levels possible. The used research methods are summarized in Schedule 1.

Schedule 1
Analysis methods on macro, sectoral and micro level

Methods	Macro level	Sectoral level	Micro level
Literature analyses	X	X	X
Regression analyses	X		X
Growth accounting analyses	X	X	
Input-output analyses		X	
Partial analyses	X		
Case study based analyses		X	

Schedule 2 states the conceptual frame of the analyses schematically: from the interaction of the different influencing factors result the effects on the international competitiveness of the economic and technology location of Germany as well as on production and factor input. In doing so, the mutual interdependencies between production growth, productivity growth and employment growth on one side and the research and innovation on the other side is here in the center.

Schedule 2
Flowchart of the conceptional framework



2. Economic and technological development

Economic development

In the long term, most industrial countries show a positive employment growth. However, external shocks such as the worldwide economic crisis or the raw material crises of the 1970s have an effect as well on the employment like the catching up processes in the post-war period.

Figure 1 makes clear the interaction between the production growth, productivity growth and employment growth. Following a dynamic economic development in Germany in the 1960s, a new upturn phase, which was also supported through the technical progress, started in the beginning of the 1980s. The production growth surpassed that of the productivity, so that employment was created. After a – among other things unification caused – drop in the beginning of the 1990s, a „new economy" effect occurred, even though it was less expressed as, e.g., in the USA. The employment effects were initially positive, but then the simultaneously rising productivity on the one side and flagging economic situation on the other side had a negative effect.

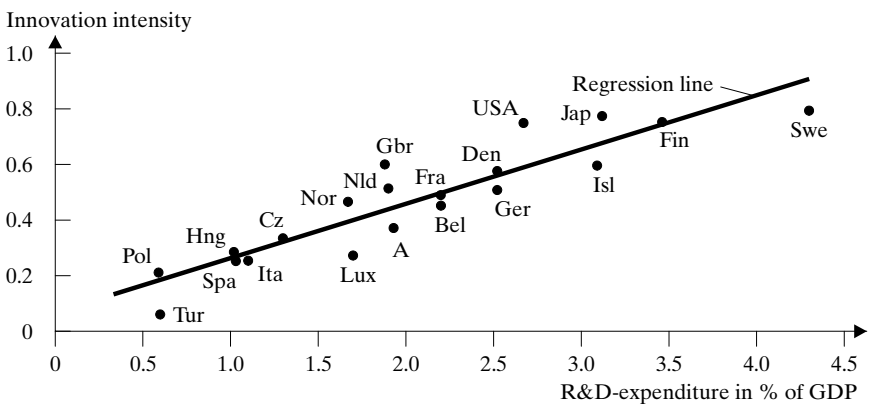
Figure 1
Real value added, labor productivity and employment
1960 to 2003; change against previous year, %[1]

Authors' computations based on Rothgang/Dehio/Lageman et al. (2004:16). – [1]Until 1991 West Germany. Five-year moving averages.

Technological development

Innovation can be illustrated through different indicators (research intensity, patent applications, quotation indices, innovation surveys). The structure of the R&D expenditure differs fundamentally from the diffusion patterns of the innovations, which is connected with the fact that gained knowledge through spillover effects can be transferred by R&D, so that innovations are also supported in countries, sectors and enterprises, which are less research intensive. Nevertheless, the connection is relatively close between research and innovation, at least on an aggregated level (Figure 2).[1]

Figure 2
Research and innovation intensity
2002



Authors' computations based on data of the OECD (2004a) and the European Innovation Scoreboard (2003).

The research intensity, which expresses the effort towards the generation of new technological knowledge, represents therefore a frequently applied indicator to the illustration of the innovativeness of a country. With regard to the level of research intensity, Germany is, in international comparison, in the upper third of the OECD countries, however, has fallen back compared to, among others, USA and Japan. Also with regard to the patent applications, Germany has fallen back in the international comparison in the 1990s.

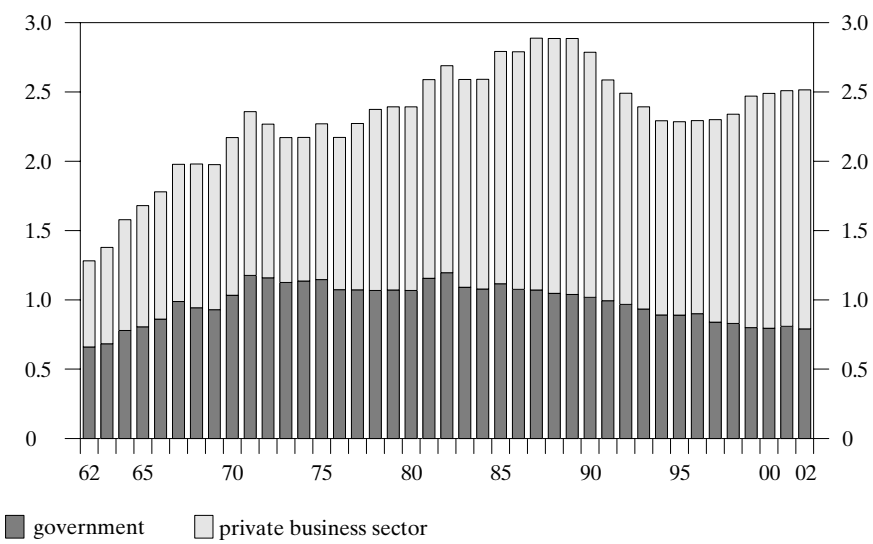
[1] The innovation intensity is on 1 standardized indicator, which consists of 12 partial indicators, including indicators for human resources, patents and for R&D as well. In this respect, a part of the very close correlation of both data rows (determination coefficient of 84%) is to be explained with the fact that the innovation intensity is also affected by R&D indicators. However, for Japan or the USA, there is no better way to represent innovation performance. Also for EU countries, CIS data are only available for some years.

At the level of the R&D expenditure, among others, the development level of a national economy, the economic structure, the institutional arrangement of the innovation system, the innovation responsiveness of the general framework conditions, the openness towards new technologies, and finally, economic dynamics have an effect. Figure 3 shows the long-term trend of the research intensity in Germany, which was characterized for decades by increases, before it came, in the beginning of the 1990s, to a decrease, among other things, caused by unification. Since the 1970s, the government-financed R&D intensity has decreased continuously.

According to the empirical findings, Germany still plays a technological role, which is like before significant in the world-wide standard. However, it was also shown that in the international comparison the position has worsened during the 1990s. Promising high tech industries settle in other countries, the USA and Japan have supremacy in the area of high tech. Moreover, our analyses give various indications to the fact that German enterprises shift their R&D departments more and more abroad.

Figure 3

R&D-expenditure in Germany by type of financing
1962 to 2002; in % of GDP



Authors' computations based on data of the BMBF (2004).

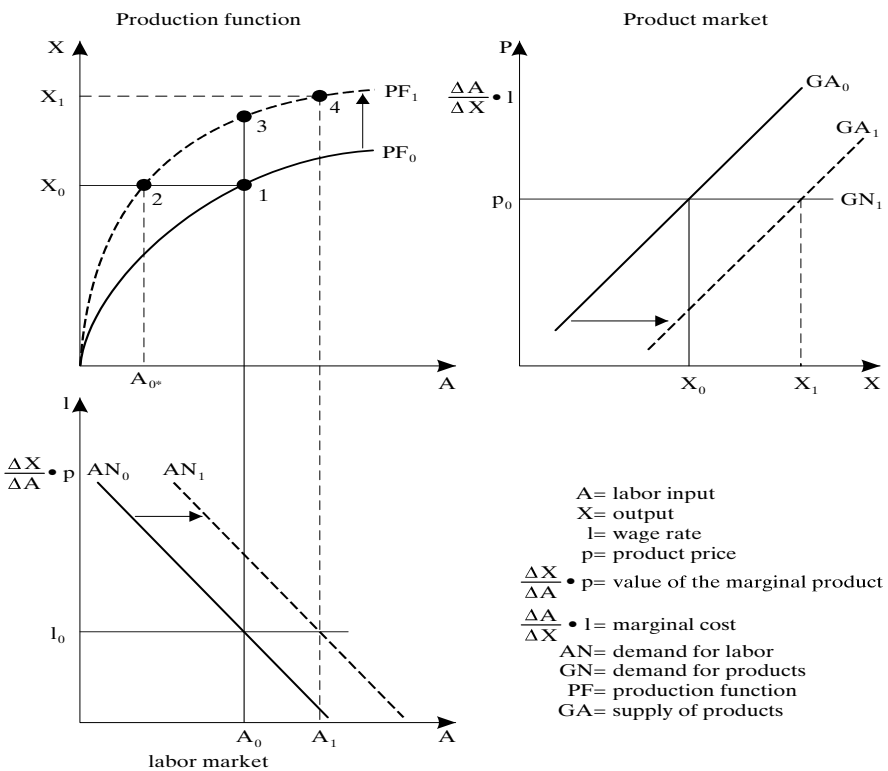
3. Findings of the analyses

Findings on the macro level

High-developed industrial countries show compared to newly industrialized countries generally lower growth rates regarding the gross domestic product. Simultaneously, they score, however, comparatively high per capita income and a large research capital stock. For these countries, a substantial need exists on the basis of their supply and demand conditions to compete successfully through permanent research and innovation. A country, which is a technological and an economic leader, must develop continuously new products and procedures to be able to occupy promising human capital intense and knowledge-intense markets and to be able to hold thereby its prosperity level and level of employment. Our analyses indicate that Germany has good chances to transform intensified knowledge generation into growth and employment.

Figure 4

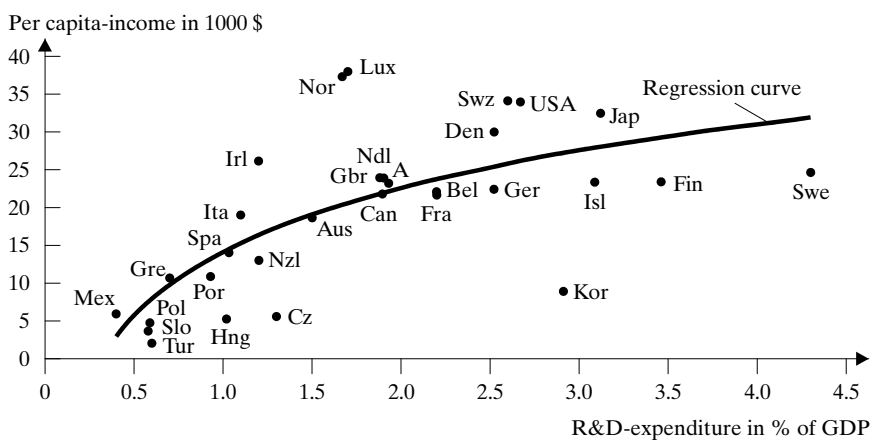
Partial model for the depiction of a process innovation on the product and labor market – perfectly elastic demand for products



The effects of innovations can be shown with the help of a *partial model* using the example of a process innovation (Figure 4). Through this innovation and an accompanied shift in the production function, the labor input falls with unchanged output x_0 to A_0 (maximum dismissal effect). With unchanged labor input, the production is raised by the difference of the points 3 and 1. These are both the technical progress classic-wise ascribed effects. Under the assumption of constant product prices (elastic demand for goods), the labor input is raised to A_1 and the output to x_1 (maximum net employment effect). Therefore, the price elasticity of the goods demand is of central significance: The more inelastic the demand is, the lesser the direct employment effects or the greater the short-term dismissal effects and vice versa.

However, in the case of dismissal effects through productivity-increasing process innovations, compensation effects arise at the overall economic level (e.g., purchasing power and competition effects), while the positive direct employment effects of product innovations are confronted with short-term negative substitution effects (budget restriction). However, adaptation frictions of, for instance, changed human capital requirements lead to the fact that necessary adaptation processes are delayed. Moreover, not every innovation effort leads to the economic effects in the described sense. In this context, the research activities, which represent the prerequisite for innovations, are of central significance.

Figure 5
Research intensity and per-capita income
2002

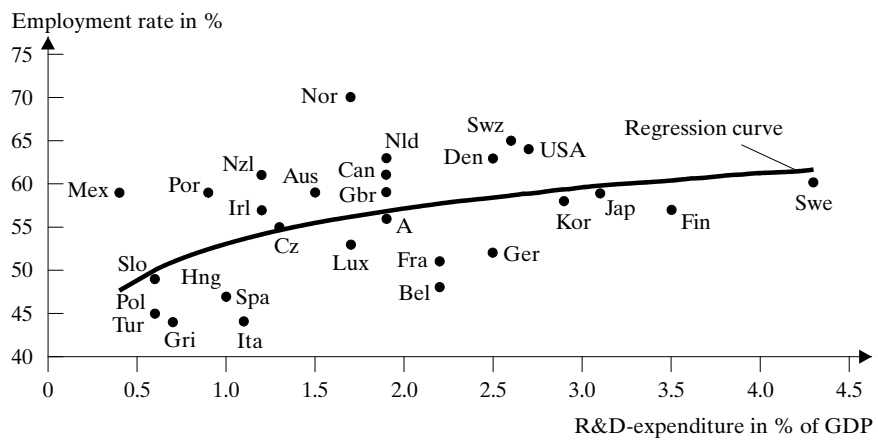


Authors' computations based on data of the OECD (2004a).

The level of the research intensities and the per capita income are closely positively related to each other (Figure 5). Therefore, research-intense countries possess evidently a comparatively higher economic capacity. The background of the close relationship is to be seen in the fact that the technological competence of an economic location is shaped to a large extent by R&D activities. The higher the national economy is developed, the more it must invest in the knowledge generation to be able to maintain its living standard; however, the scope will also become greater for increasing R & D-expenditure. However, evidently the law of diminishing returns is also applied to R&D. Therefore, it will be increasingly more difficult with rising research intensity to use the additional R&D expenditure even more effectively.

In the consideration of individual countries, investing samples appear: On the one hand, Germany lies just under the regression curve. On the other hand, for instance, Japan and the USA – register not only higher research intensities, but also far higher per-capita income so that they lie significantly over the regression curve. The reason for that finding will be given in more detail later on.

Figure 6
Research intensity and employment rate
2002



Authors' computations based on data of the OECD (2004a).

The connection between the *research intensity* and the *employment rate* (Figure 6) is by far not as close as, e.g., between the research intensity and the per capita income. This is connected with, among other things, the fact that the employment rate is affected by numerous other factors, such as demographic development, immigration, labor market rigidities, changes of

the acquisition behavior (e.g., concerning the labor force participation of women), labor market-political measures (e.g., job-creating measures, mini-jobs etc) and, not least, statistical recording problems.

A high employment rate means that a high quota of people between 15 and 64 years of age pursue a job. It also is therefore a particularly appropriate indicator to the representation of the employment level of a national economy, because the self-employed and unpaid family workers are also considered.

The relationship, which is revealed here, shows that obviously the expansion of the employment rate is accompanied by an increase in the research intensity at least in tendency. Also with regard to the employment rate, Germany does not come off particularly well and lies relative clearly under the regression curve.

Special interest is considered to the question whether the apparent existing efficiency differences between Germany and, for example, the USA and Japan are due to the conversion from R&D into growth or other causes must be held responsible. To follow this, a *growth accounting approach* was used in connection with a regression analysis.

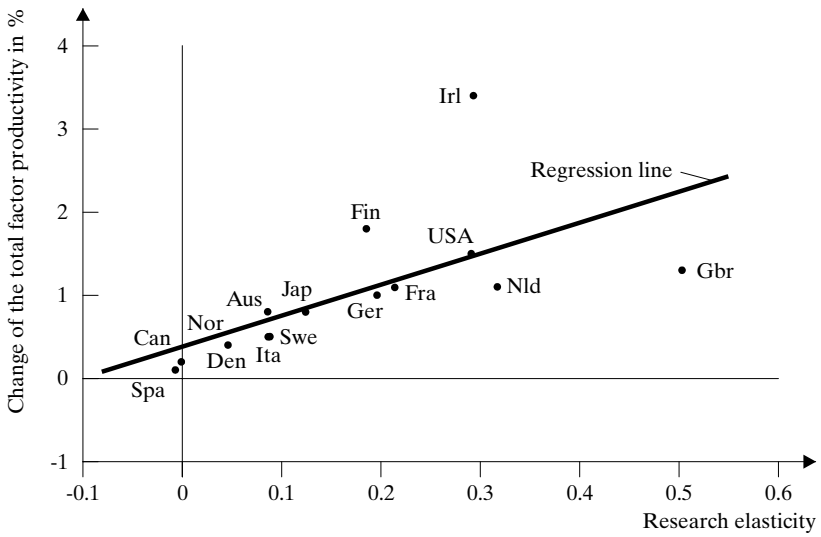
Thereby, it is shown, to what extent the accumulation of knowledge through the expansion of the research capital stock is converted into technical progress (Figure 7). Economic growth and employment are affected by the changes of the total factor productivity, which arises as a residual if the influence of the changes in labor and capital input is singled out. Therefore, the growth rate of the *total factor productivity* represents the rate of the technical progress.

For selected countries, the long-term growth of the total factor productivity and the research capital stock were calculated and from that *research elasticity* regressed. This elasticity expresses how the total factor productivity changes if the research capital stock rises by 1%. According to that, between the research elasticity and the technical progress a positive relationship exists. The knowledge generation increases therefore the economic capacity of a national economy: The more distinct the ability is to convert the accumulation of knowledge into productivity growth, the higher is the rate of technical progress in tendency.

If one compares the research elasticity of Germany, the USA and Japan, satisfactory values appear for all three countries. Germany records compared to Japan an equally higher total factor productivity and a much higher research elasticity. If one considers this in connection with the empirical findings of the relationship between the level of the per capita income and

the research intensity, the conclusion must be drawn from here that the comparatively unsatisfactory income level in Germany is not due to a lack of ability to convert knowledge into technical progress.

Figure 7
Technical progress and research elasticity
1975 to 2002



Authors' computations.

The countries-specific differences shown above are due, among other things, to the following causes:

- The diffusion patterns of the innovation and the level of human capital can differ from country to country.
- Industrial countries follow different technological paths and innovation paths, which shape the patterns of these innovations.
- Different socio-economic, institutional, cultural, legal and political general conditions can exist.

As already explained, Germany has fallen back with regard to the level of the research intensity – with a considerably high basis level – in the international comparison in the last two decades. Moreover, the growth rate of the research capital stock is comparatively low. The rather high research elasticity with simultaneously only average growth of the research capital stock suggests that an increase of the growth rate of the R&D expenditure would

be meaningful, because this would have an evidently positive effect on the technical progress in Germany. However, building-up of a knowledge capital stock is connected naturally in principle with expenses: therefore, expenses for R&D compete with alternative allocation of funds. The possible growth and employment effects induced by the innovation process are dependent therefore crucially on the efficiency of the R&D allocation of funds. It is to be assumed that a pronounced ability to convert knowledge into technical progress has a positive effect on the employment in the end. However, this can be proved only with the help of multivariate analysis procedures.

A significantly positive influence on the growth and, to a lesser extent, also on employment could be proved by means of a multivariate panel analysis for the R&D expenditure of the economy and for the university sector as well as for patents. No or only a weak significant effect is ascertainable for the entire governmental R&D expenditure. However, it can be explained due to the fact that the governmental R&D expenditure aim partly also at areas of special public interest (e.g., energy, health), which can in general contribute to the creation of marketable products and processes to only a limited extent. According to the analyses, the employment growth declines with rising wages and the level of employment already reached.

Considering the empirical findings at the macro level, the German innovation system is still to be judged as efficient with regard to the transformation of knowledge into technical progress and, as a result of it, also into employment. The unsatisfactory level of the per-capita income and the problematic employment situation seem therefore less due to inefficiencies in the area of research and innovation. Therefore, other causes must be held responsible for this (e.g., rigidities, shortages in human capital). Nevertheless, the fact that the development of the research and innovation intensity has lost some of its dynamics is to be critically considered.

Sectoral level

In Germany, the *patterns of sectoral change* dominate, which is also observed in most developed countries, according to which the technical progress leads in the form of rationalization investments in industrially shaped branches tendentiously to a decrease in employment. The employment losses in the manufacturing industries – a further trend in developed countries – are confronted with the gains in employment in the service industry. In Germany, the employment declined in the 1990s, however, also in some technology-intense service industries. In some areas, it lacks, primarily, a consistent orientation towards future technologies. Although, Germany has a position, which is outstanding world-wide in energy, production, environ-

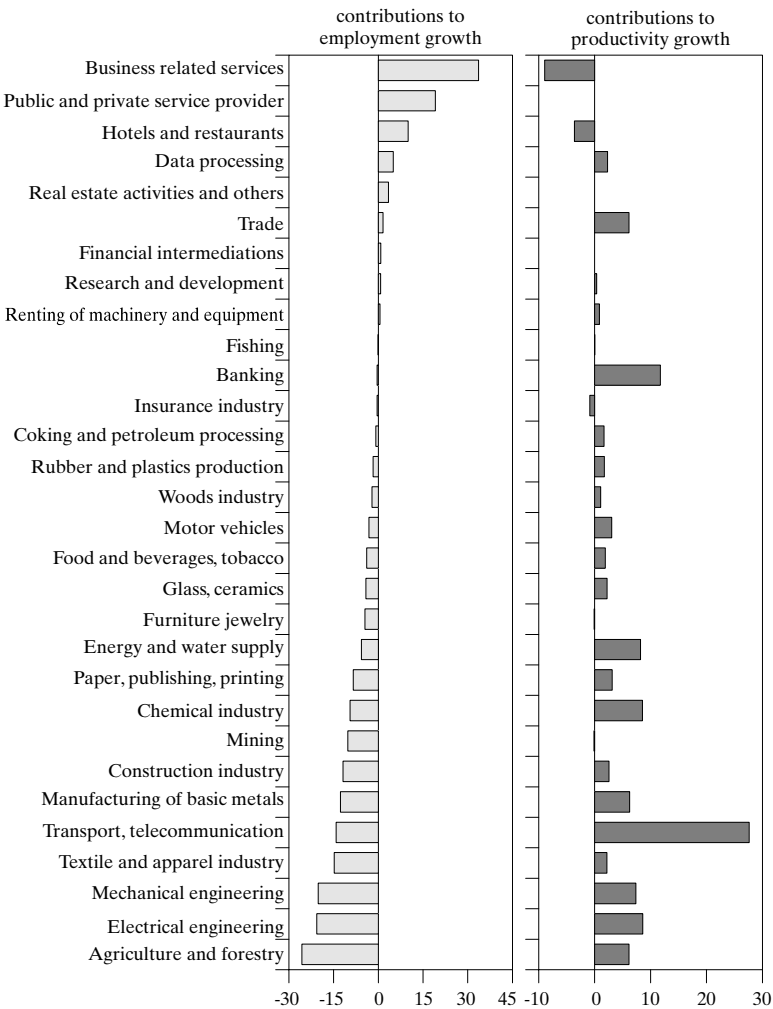
ment and transport technology, other areas still need to catch up in spite of a good basis and hopeful approaches, for example, in the biotechnology and gene technology, in the micro and nanotechnology, with new materials or in the space technology. Therefore, Germany has adapted partly relatively late to different technological developments of knowledge-based economies and therefore has changed the structures not enough until now.

Germany has international competition advantages more in traditional, technology-intense sectors. Besides, it is concerned with research-intense branches, which are based on accumulated experience. While this, with regard to the employment development at least for the 1980s is confirmed, the outcome of these branches was in the 1990s comparatively unfavorable (Figure 8): No sector of the manufacturing industry shows a positive contribution to the employment growth in this period. Also, in some technology-intense service industries (transport and communication, energy supply and water supply), the employment dropped.

Partly, substantial differences will be considerable in the growth processes for central sectors of the manufacturing industry: In Table 1, the growth contributions, which are calculated by means of a *growth accounting analysis*, show how strongly the use of different production factors has contributed in the concerning period to the net value added development. A positive growth contribution of the working volume is to be observed only in the 1980s and in the second half of the 1990s, as well as until the middle of the 1990s in the financial services industry. The contribution of the labor quality to the output was positive in all sectors. In this context, the more intense use of the information and communication technologies (ICT) played an important role. This points to a large significance of rationalization measures for the employment development.

Innovations diffuse in the entire economy, while private research and development events concentrate on relatively few branches, which are settled primarily in the manufacturing industry. Therefore, the connections between research, innovation and employment were examined within the framework of five industry analyses (motor-vehicle industry, mechanical engineering, chemical industry, electrical engineering, financial services), whereby the selected branches are characterized in the sector comparison by high research intensities.

Figure 8[2]
Annual contribution to employment and productivity growth by sector
1991 to 2001; in %



Authors' computations based on data of Statistisches Bundesamt.

[2] The contribution of a sector to the growth of the working volume was calculated by multiplying the share of a sector in the working volume of 1991 (working hours per mil. employed people) was multiplied by its average annual growth rate between 1991 and 2001. The contribution to the productivity growth is calculated from the share in the added value of 1991 (gross added value per employed person) multiplied by the average annual growth (1991/2001).

Table 1
Growth contributions of the production factors by sector
1980 to 2001; annual average growth rates in %

Period	Chemical industry	Mechanical engineering	Electrical engineering	Motor-vehicles	Financial services	Overall economy
			Growth of value added			
80/90	2.42	1.63	6.84	2.77	3.37	2.33
90/95	3.03	-3.45	-2.5	-2.18	2.89	1.90
95/01	0.27	0.16	7.16	-0.03	3.86	1.96
			Contribution of working volume			
80/90	-0.04	-0.07	0.17	0.25	0.74	0.17
90/95	-3.24	-4.73	-3.68	-3.23	0.48	-0.25
95/01	-2.28	-1.15	-1.49	2.76	-0.31	-0.03
			Contribution of labor quality			
80/90	0.28	0.40	0.53	0.24	0.15	0.35
90/95	0.33	0.61	0.63	0.40	0.21	0.07
95/01	0.16	0.14	0.46	0.17	0.08	0.01
			Contribution of ICT-capital stock			
80/90	2.00	1.73	1.60	2.14	3.24	1.67
90/95	0.70	0.44	0.78	1.05	3.63	1.24
95/01	2.19	1.29	3.36	1.82	5.93	2.68
			Contribution of non-ICT-capital stock			
80/90	-0.06	0.10	0.47	0.38	0.74	0.42
90/95	0.04	0.04	0.10	0.14	0.39	0.60
95/01	0.23	-0.04	0.00	0.05	0.26	0.55
			Growth of total factor productivity			
80/90	0.25	-0.53	4.07	-0.25	-1.49	0.70
90/95	5.19	0.18	-0.33	-0.53	-1.81	0.79
95/01	-0.02	-0.08	4.83	-4.84	-2.10	0.91

Authors' computations based on data of O'Mahony and van Ark (2003) CD-ROM.

The *motor-vehicle industry* could maintain its position – supported by the high research intensity – in the international competition. The employment development was positive in the sector comparison. Moreover, substantially more employees are connected indirectly with the final demand for motor vehicles in Germany – which an *input-output analysis* proved – than the production statistics of this industry identify. The number of the employees who depend in such a way as suppliers on the car sector has substantially risen since the end of the 1970s. If one includes the indirect employment effects, the employment has risen in the 1980s as well as in the 1990s. In this context, the closer linkages with the business-related services play a central role. Nevertheless, new jobs have been created to a large extent abroad (particularly in Eastern Europe). This trend was covered so far only by the positive overall development of the German automobile manufacturers. For the near future, further production relocations are to be expected.

Also, in *mechanical engineering*, in spite of the decline in employment, important parts of this sector remain internationally competitive because of

successful innovations. However, numerous enterprises in mechanical engineering are currently considering moving production capacities abroad. Certainly, many negative scenarios are exaggerated. However, through the high labor cost in Germany it is to be expected that in this sector a stronger concentration on technological high-quality engineering products will take place. At the same time, the size of the market is very limited internationally. Therefore, employment growth is not to be expected in the medium term.

Particularly attractive are services sectors, which offer qualified jobs, like, for example, the *banking sector*. The banking sector is, as well as other service industries, an intense ICT user. It has been apparent for a long time that through the diffusion of innovations – like, for example, the electronic payments and the expansion of cash dispensers – efficiency capacities are realized, which contributed to a stagnation of the employment in the banking sector in Germany. Nevertheless, the efficiency capacities are by far not yet exhausted.

Therefore, primarily, the new knowledge-intense sectors of the economy appear as possible sources for future employment growth. Certainly, the German innovation system has its weaknesses especially in these sectors. Nevertheless, positive employment effects are to be expected here most likely. Therefore, the pharmaceutical industry and the ICT area were also investigated in more detail. The *pharmaceutical industry* is principally extremely attractive for Germany as an industrial country, because it safeguards high-qualified jobs through high productivity. Primarily, this applies to the area that develops new drugs, less to the market for generics and prescription-free drugs. In this context, the relatively high research expenditure compared to other sectors should not hide the fact that especially in the highly innovative parts of the economy the German enterprises have lost competitiveness, partially as German companies are too small measured by international standards. This has also had a negative effect on the employment in this field, although so far the employment of the sector has remained all in all stable.

The dynamic development of new technology fields has taken place also in the *ICT field* essentially outside of Germany during the last years. This shows the analysis of the development in *electrical engineering*. The production main areas of ICT are to be found in the USA and Japan, while particularly Northern European countries have profited from the dynamism of the communication technologies. However, in the course of these new technologies, some areas of the electrical engineering in Germany also recorded increases. Nevertheless, the employment effects are substantially lower than in the countries in which these technologies were developed.

New technology fields emerge in the locations, where, world-wide seen, the general conditions are the most positive, as well as the innovation willingness and innovation capacity of the enterprises are the highest. However, there are still other factors, which decide finally on the technological success, like, for example the cooperation of the different participants or the international penetration of standards. A technology-open adjustment can therefore, on the one hand, raise international competitiveness, and on the other hand, can favor the development of new industrial clusters and research clusters. Especially in the introduction phase of new technologies, governmental activities have – recent experiences reveal this – an important role. The enterprises in turn should try even stronger to connect traditional innovation processes, supported by in-plant knowledge of experience with new knowledge. This requires, like the development of the recent past has revealed, increased cooperation with other enterprises, but also with scientific research.

Micro level

The innovation behavior of enterprises can trigger different employment effects, in which at the micro level, the direct employment effects of the innovations are in the centre of interest. The micro-economic analyses with which the partial employment effects of individual types of innovation can be identified and isolated from other influences were carried out, primarily, on basis of the data from the *establishment panel* („IAB-Betriebspanel") of the Institute for Employment Research (IAB) and a SME survey of the RWI Essen.

The evaluation of the data from the IAB *establishment panel* shows that more than one quarter of the enterprises per year introduce at least one product innovation (multiple responses were possible): In 22% of the enterprises, this referred to improved products, about 15% of the enterprises could reveal enterprise novelties, while 5% of the enterprises recorded innovations in the market which are particularly relevant from the employment perspective. If one compares the sales trend and employment development of product innovators to those of other enterprises, it appears that product innovators show nearly generally a better performance (Table 2). These findings also apply to different qualifications.

However, the comparison of the figures still allows no conclusion to the partial contribution of the innovation behavior on the operational development. It is to be assumed that both groups of enterprises – product innovators and non-product innovators – differ in other characteristic features (e.g., size, branch, employment structure, entrepreneurial skills etc) which can also have an effect on the performance. Due to this reason, econometric

analyses are indispensable in order to determine the partial contribution to employment of innovation activities. Multivariate panel analyses were carried out and the results – also according to other empirical studies – differentiated by four different types of innovation activities: product innovations, process innovations, organizational changes, investments in ICT.

Table 2
Results of the employment, sales and productivity growth as well as further educational training of non-product innovators and product innovators, in %

Indicator	West Germany		East Germany	
	Companies without new products	Companies with new products	Companies without new products	Companies with new products
	(N=991)	(N=249)	(N=1.169)	(N=275)
Employment growth 1998-2001 – employed persons subject to social insurance	-1.6	0.0	-6.0	-1.7
Employment growth 1998-2001 – qualified persons	0.4	2.3	-1.6	1.5
Employment growth 1998-2001 – skilled workers	-2.5	-3.0	-5.2	-2.7
Employment growth 1998-2001 – low-skilled workers	-4.4	-2.8	-6.7	-2.1
Sales growth 1998-2001	0.0	2.9	-2.4	0.2
Productivity growth 1998-2001	1.4	2.6	2.9	1.3
Share of companies with further educational training 1999	64.9	84.7	64.4	77.5

Source: Authors' calculations according to data of the IAB-Betriebspanel (2001); supported by the FDZ of the BA in Nuremberg; N = Number of observations.

The majority of the empirical studies came to the result that *product innovations*, including primarily innovations in the market, on average from all product innovators lead to more employment. However, the results of own panel analyses show that the introduction of enterprise novelties or innovations in the market favors the employment growth, only if there is *innovation success* in the form of achieved turnovers with new products. The innovation success depends on the market acceptance of the new product, the complementarity to the existing range of goods offered by the enterprise and the complexity of the innovation. The more complex an innovation is, the sooner a need can arise for additional staff for the product development or introduction. Positive company-size specific *employment effects* appear according to our analyses mainly in the group of the SMEs.

The results of empirical studies concerning the employment effects from *process innovations* are different. The majority of the studies connects with

process innovations neutral or negative direct employment effects. Evidently, these vary, among other things, with the economic development: in phases of economic downturn, the importance of process innovations with the aim of the reduction in costs increases, so that negative employment impulses dominate. In phases of an economic upturn, the positive employment effects are predominant on the contrary. Process innovations are used apparently to a large extent for the purpose of the increase in output. The empirical results with regard to the employment effects of *organizational changes* and the *introduction of modern ICT* show at the microeconomic level no clear picture. According to our analyses, the positive and negative effects compensate themselves for the most part.

A large number of empirical studies is devoted to the *qualification-group-specific employment effects* of the innovation. Therefore, the introduction of modern ICT and organizational changes is associated with a rising demand for highly-qualified employees. The demand for low-qualified people and, in the rule, also for medium-qualified people decreases on the contrary. Moreover, one points to the positive impulses of the introduction of product innovations, which induce the demand for highly-qualified persons. Through our analyses, it could be confirmed that the organizational change contributes to the employment dismissal of low-qualified employees. All in all, a lot speaks therefore for the fact that *further educational training* is a key factor for the employment, although our analyses proved this has only a weak significance. However, this can be due to the fact that further educational measures become positively apparent only in the long term.

The results at the micro level underline altogether that successfully introduced innovations contribute as a rule to the improvement of the competitiveness of the innovators. On the contrary, the employment effects must be considered much more differentiated. In this context is the type of innovation and the innovation success of central importance. The higher the sales with new products, the higher the employment growth generally is. International competitiveness, lasting growth and durable jobs appear therefore, primarily, from successful innovations. To be able to survive in the intensifying international competition, the permanent development of innovations and their quick transformation into marketable products and processes will become even more important in the future.

Links between the analyses of the macro, sectoral and micro level

The question to be treated within the framework of this research project was of an extremely complex nature. Although, numerous aspects relevant to the subject are not sufficiently clarified in the economic based innovation research until now, the attempt was nevertheless undertaken within the

framework of this study to provide an extensive picture about the likely employment effects from research and innovation. On the one hand, the analyses carried out here indicate that politics should do everything in their power to strengthen the research and innovation force of Germany. In doing so, policy makers can influence the growth of employment positively, especially in the long term. On the other hand, no doubt can exist that this is an exceptionally demanding task, which by no means promises rapid and effective success in the course of its accomplishment.

The following can be derived from the results of the study:

- The knowledge generation by R&D is crucial for the technology competence and the innovation ability of the economic location of Germany.
- All in all, the conversion of this knowledge into innovations has a positive effect on growth and employment.
- The research and innovation intensity should be raised therefore in the long term, under the prerequisite that the efficiency of the R&D funds is guaranteed.
- R&D or innovation-induced growth and employment effects depend to a large extent on the institutional and political general conditions.

The results of the study underline, why the overall economic, sectoral and single plant levels should be considered in each case separately: While at the macro level, the employment effects from research and innovation are examined under the inclusion of national economic compensation and substitution processes, industry analyses identify the employment-specific peculiarities of sectoral innovation processes. Analyses at the micro level make possible the identification of direct employment effects and the investigation of the company-size and qualification effects.

For the transition to the innovation-political options to act, the Table 3 puts for the largest EU countries, USA, and Japan some of the empirical findings of the study together with other locational indicators. Germany has, in almost all indicators identified, less favorable values compared to Great Britain and Japan as well as particularly the USA, what points to negative locational factors with regard to growth and employment. Problematically, primarily, is the combination of weak economic data (concerning stock figures as well as the long-term development), comparatively low innovation measures as well as, in the international comparison, pronounced labor market rigidities and high effective tax rates. In view of this relatively desolate overall picture, the level of the research elasticity is still hopeful.

Table 3
Selected locational indicators in international comparison

Indicator	Ger	Fra	Gbr	Ita	Jap	USA
			Economic-relevant stock figures			
Per-capita income (in US-$/inhabitant, 2001)[1]	22	22	24	19	32	34
Employment rate (in %, 2002)[2]	52	51	59	44	59	64
Unemployment rate (in %, 2001)	7.8	8.5	5.0	9.4	5.0	4.8
			Innovation ratios			
Research intensity (in % of GDP, 2002)	2.5	2.2	1.9	1.1	3.1	2.7
Innovation intensity (on 1 standardized index, 2002)	0.5	0.5	0.6	0.3	0.8	0.8
Education intensity (in % of GDP, 2001)[3]	5.3	6.0	5.5	5.3	4.6	7.3
			Annual average growth rates			
Real GDP-growth (in %, 1975-2002)	2.5	2.5	2.9	2.7	2.9	3.7
Employment growth (in %, 1975-2002)	0.5	0.3	0.8	0.2	0.8	1.8
Technical progress (in %, 1975-2002)	1.0	1.1	1.3	0.5	0.8	1.5
Growth of the research capital stock (in %, 1975-2002)	3.7	3.6	2.4	3.2	6.1	4.4
			Transformation of knowledge into TFP[4]			
Research elasticity (coefficient, 1975-2002)	0.20	0.21	0.50	0.09	0.12	0.29
			Degrees of rigidity			
EPI-index (1999)[5]	2.6	2.8	0.9	3.4	2.3	0.7
NAWRU-index (1995-2001)[6]	7.1	9.7	6.1	9.9	3.5	5.3
Effective corporate tax rates (in %, 2003)[7]	36	33	29	33	-	-

[1]In current prices. – [2]Employed persons related to the people at the age of 15 to 64. – [3]Expenditure for education facilities (cf. OECD 2004b: 229). – [4]Regression of TFP (Total Factor Productivity = technical progress) with growth of the research capital stock. – [5]EPL (Employed Protection Legislation) is an indicator for rigidities caused by labor protection regulations (the higher, the more rigid; cf. SVR 2002: 214). – [6]NAWRU (Non-Accelerating Wage Rate of Unemployment) is a measure for labor market rigidities (the higher, the more rigid; cf. SVR 2002: 214). – [7]Incorporated companies (according to the calculations of the ZEW), Germany 2004.

4. Options to act for the innovation policy

The locational quality of Germany – that is the attractiveness for mobile production factors – has clearly decreased all in all since the beginning of the 1990s. This is associated partly with the fact that less developed countries have caught up and thereby have changed the relative competition position. Moreover, one has not succeeded so far in moving upcoming structural reforms to a sufficient extent since some time. Suggestions for a solution of the employment problems in Germany should particularly consider the factor markets in connection with the world-wide economic and technological development. The field of innovation must be integrated into the reform efforts much stronger than before. The innovation policy should serve as the improvement of the international competitiveness of the eco-

nomic location and technology location of Germany by creating framework conditions that support both research and innovation.

However, what can, and what should politics do? Our plea amounts to an intense innovation offensive, which coordinates all relevant policy areas in a very coherent way. Concerning the existing need for economic-political advice, proposals for options of innovation policy to act cannot fall back in a lot of cases on accurate empirical knowledge. With regard to a great deal of questions, therefore, there also is further need for substantial analysis. In the following, however, this should not be an obstacle to discuss extensively the political options to act. Due to the fact that it concerns employment effects from research and innovation, it seems reasonable that the following discussion of the options to act is not only concentrated on technology policy in the narrow sense, but also on the extended political environment.

A. Creation of favorable general framework conditions for research, innovation, growth and employment

Creation of an innovation-friendly atmosphere in Germany

One of the findings of the study is that the employment effects from innovations are determined considerably by the demand elasticity. In connection with the declining *price and income elasticities of the quantitative demand* as a result of partial satisfactions in traditional markets, product innovations are therefore of large significance, because new products show much higher demand elasticity. Politics should therefore strengthen their efforts, primarily, to create general conditions for a very positive supply and demand development of these new, innovation-intense and fast-growing products or markets. This would be – as our analyses reflect – an essential starting point for the generation of employment effects.

With all legitimate interest in the control of the complex consequences of the technical progress, the creation of an atmosphere, which supports innovation, requires particularly the reduction of an excessively critical attitude, and thereby a *greater openness towards new technologies*. The development of top technologies was hindered by *problematic legal regulations* partly. However, growth-intense and innovation-intense markets should not be adjusted if possible according to the advised extent. Many laws, which are well-mend, appear restrictive in respect of research and innovation. The same applies to a *too large extent towards bureaucracy*.

To create positive general conditions for innovative actions, the excessively *complicated tax system* would have to be simplified. The – as shown – tax rates, which are still too high, are to be brought to an internationally competitive level, what would be an advantage for the locational attractiveness.

There is also the danger that direct investments are increasingly less likely in Germany, due to bureaucratic regulations and a partly negative public opinion, primarily, in the area of some of the new technologies. In addition, the *non-wage labor costs* are, as a consequence of the demographic change and the associated difficulties with the social security systems, at a high level. This could compel German enterprises to move their activities increasingly abroad. Current RWI projects in connection with the „MittelstandsMonitor" (SME Monitor) prove that the relocation tendencies have increased in recent years. Also, the present study presents numerous indicators to support this. *Deregulation measures, reduction in bureaucracy as well as tax, social government and labor market reforms* could serve to create general conditions, which support innovation and growth.

With the Agenda 2010, an overdue reform course was introduced. The aim of the Agenda is to coordinate optimally the upcoming reforms of the labor market with the welfare state reforms. These reforms belong undoubtedly to the most important tasks of the coming years to protect the long-term competitiveness of the economic location and technological location of Germany. However, in addition, extensive efforts are also necessary to align the German innovation system with the new challenges. Innovation policy must be embedded in the future much stronger in the labor market, welfare state, government and education reforms. An extensive reform agenda, which makes research, innovation, human capital, growth and employment to its central business fields, is therefore required.

Logically consistent reduction of rigidities

Under allocative perspective, the product prices and factor prices fulfil their steering function efficiently only if they can rapidly react to changes of the supply and demand relations on the product markets and factor markets. Distorted prices, wages and interest, possibly as a result of product or factor market rigidities, cause distorted competition and inefficiencies with the consequence of a sub-optimal resource allocation. The estimation that the German economy distinguishes itself through a particularly high regulation intensity cannot be confirmed anymore without reservation, taking into account the implemented reforms and deregulation efforts. However, considerable rigidities have remained, particularly in the labor market, which stand in the way of a higher economic dynamism. Wages, which are well over the market level, can clearly cause increased process innovation rates and thus – at least temporarily, as our analyses show – employment dismissal effects.

The reaction should be a reduction of the *price-distorting and competition-distorting rigidities* as well as a stronger flexibility, both branch-specific and

region-specific, of the *wage fixing process*. The latter would diminish the disproportions between the high sectoral productivity differences on the one hand, and the comparatively low wage differences on the other hand. Positive growth and employment effects through innovation to a larger extent could be developed through a corresponding increasing *spreading of wages*.

In connection with the challenges of the globalization and the European integration (Eastern enlargement), it has become more important than ever to guarantee functioning product markets and factor markets by a reduction of *obsolete institutional structures*. In this connection, the collective agreement parties have a central role, which could have a positive effect on innovation and employment through *employment-friendly wage settlements* and *working hours regulations* as well as an expansion of opening clauses. Moreover, favoring the further *loosening of employment protection rules* could have a medium-term effect, through which the rationalization pressure and thus the excessive process innovation rates would be decreased. However, the effects of a reduction in protection against dismissal should not be overrated, particularly as the actual extent of the employment effect, according to present studies, is controversial. Nevertheless, it is undisputed that a too strict protection against dismissal can represent an attitude obstacle.

Particularly the – as the values of the specified degree of rigidity show – *high regulation intensity on the labor markets*, which are still too high, could be responsible considerably for the recent increasingly revealed weakness of the economic location of Germany with regard to growth and employment. The consequence of a deregulation would be therefore an intensification of the competition and thereby, among other things the induction of growth investments and expansion investments, which increase employment, instead of principally rationalization investments. Meanwhile, the upcoming fundamental reforms in the labor markets were introduced by the *Hartz laws*. These reforms should go further in connection with the results of the current scientific evaluations, which could give explanations about the effects of the previous measures.

Partial need for improvements in patent law

With the help of the patent law, an incentive is created for the generation of knowledge. The patent law opens simultaneously the possibility for the transmission of knowledge. By this means, the innovator receives license fees as compensation for the expenses occurred through the knowledge production. Thus, mental property becomes tradable. The patent law was developed in the past according to the technological change, so that the positive external effects, arising from innovations (*knowledge spillovers*), are internalized in the best possible way.

Our analyses support that the patent events of substantial significance are. Therefore, positive employment effects arise from a rising patent intensity. As well as the German one, the European patent law has proved itself as very effective and helpful for the innovation area. Nevertheless, in the course of the technical progress, a need for adaptation will arise in the future again and again. In view of increasingly global growing technology markets, this is a demanding, but nevertheless, a necessary task. A *simplification* and *shortening* of the *patent testing procedure* as well as the *reduction in the expenses* for such procedures would be in regard to the stimulation of inventions urgent.

B. Innovation policy across different areas

The accumulation of human capital in a country has a large significance for the production of elementary innovations. The *promotion of education* and *basic research* are the most characteristic tasks of the government. Following the economic rationale, the appearance of external effects is the real reason for governmental action for innovation policy across different areas. In this case, actions have to be taken pragmatically because neither the extent of external effects is assignable accurately nor appropriate instruments are available to internalize this contemporarily. The problem, which innovation policy has, primarily, in the area of accumulation of human capital, exists in the fact that the technological changes take place partly at rapid and further increasing speed, while the measures, which serve the accumulation of human capital, cover normally a longer time period. As shown, Germany invests, in the international comparison, however, too little in education. Therefore, one has reacted not adequately so far to the challenges to accumulation of human capital, caused by globalization and technological changes.

Improvement in schooling as basis of human capital accumulation

An important element of the accumulation of human capital is the *dual system of school and professional education* in Germany. It is regarded in the international standard as exemplary and is marked by substantial strengths. Recently, however, doubts regarding the quality of the school education have become known. Additionally, the future suitability of the German educational system is not regarded as indisputable. Because the general school education is for the accumulation of human capital of a country of great importance, the causes of possible weaknesses are to be identified and to be remedied.

As already explained, particularly the *shortcomings with regard to the requirements of new technologies* (e.g., in the ICT area) have increased in re-

cent years, which impaired the employment chances for domestic employees and triggered a reinforced *need for immigration.* As a response to this, initiatives in the school area should be evident, so that pupils are driven early to new technologies. By this means, their future labor market chances could be improved most likely. Moreover, this would be a contribution to the long-term protection of the technology and business location of Germany. Primarily, it is important that the children and young people are not confronted with the supposed dangers or threats of the technical progress, but rather their interest in it is to awake.

Improvement in education and further education

As our analyses underline, the introduction of innovations is often accompanied by a rising demand for highly qualified people and a declining demand for low-qualified people. However, changed qualification requirements as a result of the technical progress can lead to partial labor deficits – which could slow down the rate of growth – or to an excessive *dismissal of low-qualified workers*, who at first cannot find alternative employment. The reason for this is lacking sectoral and spatial mobility of the human capital factor. The discussion about the lack of expertise in recent years revealed the problem that required and supplied qualifications are, in some areas, strongly mismatched („mismatch unemployment"). From that, a substantial business need results in the qualification field.

The measures in the area of education and further education are aligned stronger than before to the requirements of a knowledge-based society, which is marked, among other things, by permanent technological changes. The measures should be adjusted to those in the university field in order to react differentially to changed qualification requirements. Finally, the basis for the long-term quality of the human capital factor is created through education and training. Undesirable developments in this field would have far-reaching consequences for the innovation ability, and thus the future growth and employment development of the location of Germany.

Quality improvement in basic research and university education

In the field of basic research which support represents a primary governmental task and is, primarily, a domain of the universities and the extern university research facilities, the expenses of the knowledge creation often face no direct returns. Therefore, it serves, primarily, the cause of extension of general knowledge and thereby the improvement in the scientific capacity of a location. However, it represents the basis for an effective applied research and is, therefore, also relevant to innovation. The most important instrument for the long-term support of the basic research is the institutional

promotion (basic financing). In addition, a project-related promotion by research assignments takes place.

Our analyses point towards *positive growth and employment effects of the R&D expenditure for the universities*, however, this should not mean that there are no efficiency reserves in this field, particularly as the colleges have a supporting role with regard to the accumulation of human capital. Germany still shows a below average quota of university graduates in the population, however, an above average time spent at university. An innovation-orientated reform of the university and the *creation of competition structures* could raise their capacity further. Above all, the measures are to be aligned in such a way that important key qualifications are provided more in the area of new technologies in order to guarantee a more effective adaptation towards technology-conditional changed requirements.

C. Innovation policy in the narrow sense

Innovation policy in the narrow sense encloses supporting measures that have an effect directly on the research and innovation of enterprises. It concentrates mainly upon the *promotion of the use of new technologies*, *of research cooperations as well as of innovative SMEs and enterprise start-ups*. Technology policy pursues particularly the aim to improve the transfer of technology. It orientates itself as a rule on promoting criteria like, for example, the size of enterprise or certain technologies (e.g., key technologies, generic technologies). *Instruments are, among other things, subsidies, credit and participatory financing.*

Possibilities to assess technology policy relastically

The economic necessity for special technology policy is undisputed principally. It results from the existence of external effects which can lead to the fact that R&D expenses decline below the national economic desirable level, if no sufficient incentives exist, which are generated with the cost-associated knowledge production. New technological trends would be thereby anticipated only with a delay. The *task of the government* is therefore to internalize the external effects with the help of appropriate instruments.

Technology-political measures can be supporting, encouraging or initiating in regard to innovation efforts. However, they should be embedded well in the context of innovation policy. It is important that they create *no subsidy fields*. Therefore, technology policy should take mainly an *initiating function* at the beginning of the innovation process. However, it can carry out no control function in the sense to affect the fundamental technology develop-

ment in a sustainable way. This can only be realized by the help of innovation policy as a whole.

A better utilization of the leverage effect of governmental technology promotion

Through the specific promotion of *research cooperations between universities, external university research facilities and enterprises* or enterprise organizations, efficient innovation networks should be stronger initiated and further developed. The aim of these cooperations is to network the basic research more with the applied research. On the one hand, the transfer of technology should be thereby forced, on the other hand, the diffusion speed from innovations. The governmental financing of these cooperations has a large significance because of the initiating of a possible *leverage effect*: The technology promotion activates in enterprises frequently a *signal effect* that is active in the expectation of a possible future promotion in these areas, and consequently, reinforced the research efforts.

The governmental technology promotion can induce therefore additional private research efforts. However, it could also come to a reverse effect because of „crowding-out". In this case, public R&D or innovation expenditure would replace private expenditure. Therefore, public and private R&D expenditure can be connected in a complementary or also substitutive way. Nevertheless, concerning the extent of possible leverage effects is little known to date. In this respect, there remains a need in this field for more research and evaluation. However, recent studies point to the fact that the impact of state promotion through windfall gains or „crowding-out" effects is by no means cancelled. Therefore, higher R&D and innovation intensity of promoted enterprises is, in general, significantly higher than the enterprises, which are not promoted.

The support of the Federal Ministry of Education and Research (BMBF) and the Federal Ministry of Economic and Labor (BMWA) is already aimed to a large extent towards the promotion of cooperations. Through the creation of appropriate *networks,* it is attempted to focus the technological potentials more, in order to achieve an acceleration of the generation and use of knowledge-spillovers. Politics makes use of different instruments (e.g., *engagement of intermediaries* such as transfer of technology centers or project sponsors) to make the transfer of technology as best as possible. However, in the national comparison, we could show that innovators in Germany cooperate too little to date. This could correspond with a lower utilization of the possible innovation potential. If this is the case, a higher cooperation activity would be desirable from the overall economic perspective. In connection with this, the focusing on a preferred promotion of research coop-

erations is to be greeted in principle, e.g., within the framework of the programmes ProInno II and InnoRegio, and should be further developed. However, the *competitive assignment of appropriate research projects* in the cooperation field could be carried out *taking into account market relevance and network compatibility* even more.

Risk prevention of new financing gaps

For innovative SMEs, the low company capital equipment and the lack of sufficient funds is one of the largest innovation and employment obstacles. It seems reasonable that the stagnation of the innovation expenditure of the SMEs, which was mentioned in our study, is due to, among other things, financing bottlenecks. The fears of the SMEs appear exaggerated in this context; nevertheless, this aspect is not unproblematic, because according to our analyses, primarily, *through innovations in SMEs, positive employment effects are to be expected*.

For the rapid and lasting overcoming of the financing problems of innovative enterprises, the KfW banking group has presented suggestions, from which some are of special significance regarding the results of our analyses: One suggestion („budget-compatible volume rise of the BMBF project promotion") aims to supplement the grant by an interest-subsidized, repayable and non-collateral credit in „appropriate" cases. Furthermore, „spin-offs" could be promoted through funds, which should also perform management consulting and technical advice along with the supply of risk capital. Established innovative SMEs should try to overcome financing obstacles with the help of the „*Mezzanine financing*" (junior loan): This is outside capital with a character similar to equity capital, because it is used in an insolvency case only after other bank credits, but before the equity capital. Consequently, it improves via the financing structure the credit standing of the enterprise in question and increases the time frame for the financing of innovations.

A transitional phase towards capital-market orientated financing products, like we are experiencing now, is always associated with frictions. Therefore, it is to be welcomed that the acceptance of modern financing instruments is accompanied by selective measures and is further stimulated. However, the efforts should be aimed not too one-sidedly towards an individual instrument, but include the *whole range of new, modern financing options* (e.g., leasing and its special forms), and fundamental measures for the improvement of the capital structure and representation of the financial status of the enterprises as well.

Innovative SMEs deserve special attention also, therefore, because they are central participants, if the *occupation of new markets* is of concern. In this context, a need for Germany to catch up was indicated. It is undisputed that the availability of sufficient risk capital is of substantial significance to guarantee the conversion of research and innovation into new products, growth and employment. Measures for the improvement of the general conditions – like, for example, through the *high-tech master plan* – point in the correct direction to raise the supply of risk capital. These measures are already supplemented meaningfully with specific supporting measures, e.g., the new adjustment of the BTU programm (financial support for small technological enterprises) or the establishment of risk capital funds for the purposes of a „public private partnership" to balance the lack of private investors. With the help of these instruments, it should be operated flexibly and effectively in the future. Public institutions receive here the *role of the initiator*.

Optimizing the structur of technology promotion

The structure of the technology promotion is relatively differentiated. Nevertheless, it also characterized by a certain fragmentation. In this respect, is to be considered, to what extent it would be reasonable to focus on the promotion programmes even more. In this regard, much has already been done in recent years and a lot has improved. The promotional structure, nevertheless, still appears too disparate. A particular problem represents the responsibility of different regional administrative bodies. Particularly the responsibilities between the Federal Government and the federal states should be optimized in the places where possible interfaces appear, so that the promotional effect is maximized in connection with the pursued aims. Certain problems represent the coordination with the increasingly more important EU level. In the future, friction losses should be also avoided in this area as much as possible.

Need for evaluation of public technology policy

To date, little is known about the effects of technology policy. Up to now, many evaluation studies have limited themselves (also in the absence of appropriate data) to input-orientated realization controls. Result-orientated effect analyses by means of modern evaluation methods are still the exception. Technology policy is pursued in nearly all industrial countries to a large extent. However, an evaluation culture that is sufficiently acceptable has developed neither in Germany nor in another country, which would be continually able to examine the efficiency of the technology-political measures. Research has to make increasingly sure, therefore, to develop generally accepted and meaningful evaluation methods into the determination of the causal contribution of a promotional measure. The task of the government

would be to commission regularly independent scientific facilities to apply these methods.

It should be positively noted that the government has increasingly taken care, meanwhile, of this subject. The background of this is certainly the presenting of the first effect analyses of more recent date, which were carried out by economic research institutions in the last few years, partly commissioned by the Federal Ministries. In this connection, it should also be mentioned the coordination of evaluation standards, which took place at the BMWA, through manuals to the evaluation of promotional programmes and institutions. Moreover, the evaluation of the departmental research facilities was begun by the science council. In future, these evaluation activities should be developed further in order to shape the technology policy even more efficiently.