B CORE TOPICS 2010

B 1 THE GERMAN R&I-SYSTEM IN AN INTERNATIONAL COMPARISON

The national research and innovation system and the challenges faced

Research and innovation worldwide are going through a profound transformation process. In future, it will be necessary to respond increasingly to significant problems faced by humanity in fields such as energy, climate, environment, and demography, and R&I must contribute to solving these problems. The following developments in the international innovation system have led to key challenges for the economy and the science systems of many countries:

- New demands and conflicts in the fields of energy, mobility, climate, security, and health, which will require coordinated research at various locations.
- Globalisation and the spread of research resources and expertise between increasing numbers of countries pursuing active innovation strategies.
- Intensification of competition and the acceleration of innovation processes.
- The increasing concentration worldwide of R&D activities in fiercely contested cutting-edge technologies, which are expected to generate considerable growth effects.
- Knowledge intensification and the increasing importance of knowledge-intensive services.

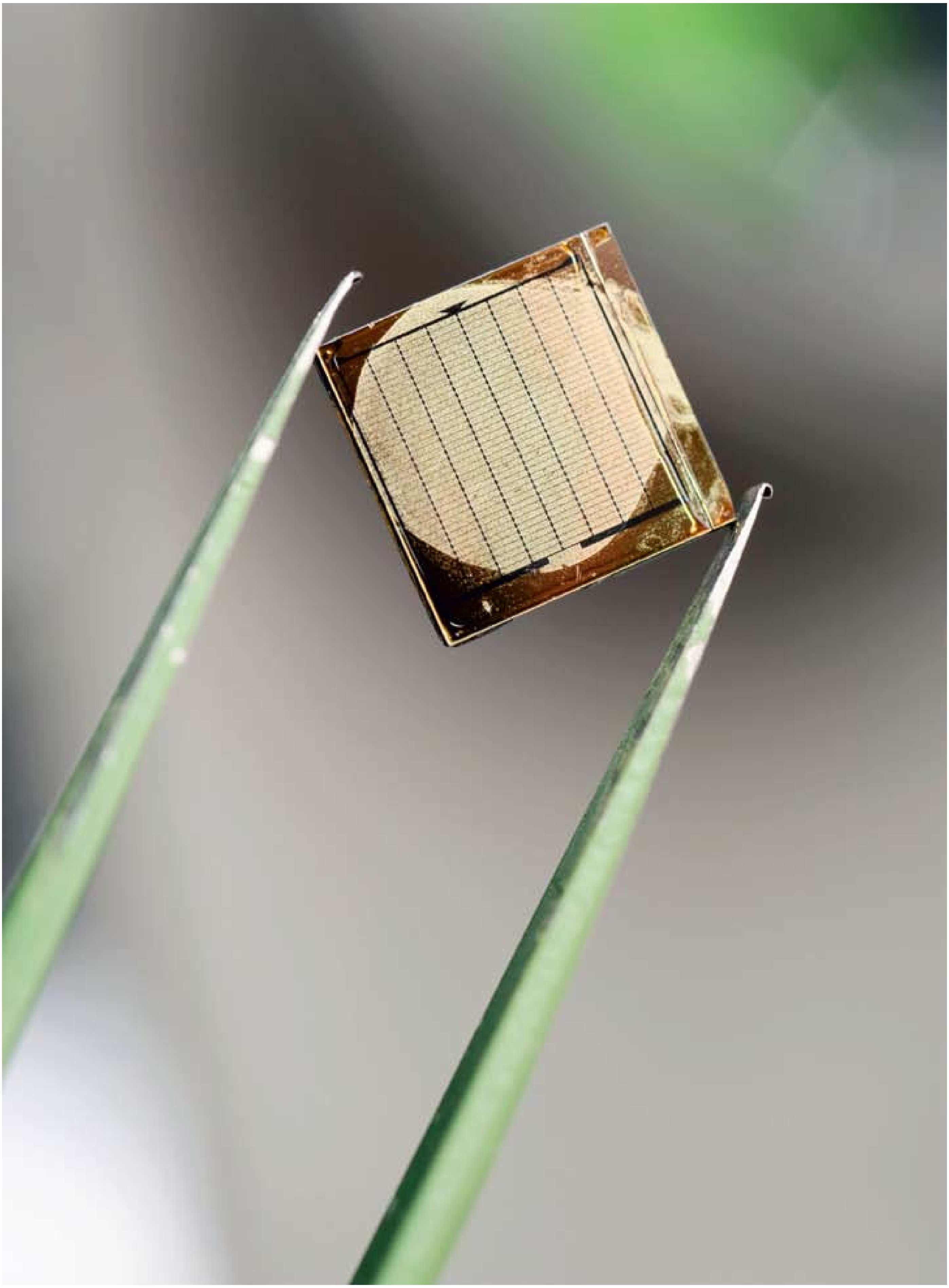
These factors are leading to a reorientation of research in the highly-developed economies. Historically evolved structures and disciplinary divisions are being overcome, the traditional division of labour between basic research and industrial innovation is increasingly being called into question and is being replaced by new organisational structures. Dynamic industries and new fields of demand are increasing becoming the focus of innovation activity, and as a driving force of innovation processes they are influencing the orientation of R&D. Demand- and problem-induced innovation is increasingly providing impulses for public research.[32]

The research and innovation policy-makers in many countries have not yet responded adequately to these structural changes. This is also the case in Germany. The German R&I system has developed considerable potential in important fields, but it must be oriented more to the challenges of the future and new topics. With the High Tech Strategy, in which the emphasis is placed on the most important fields for Germany, the Federal Government has managed to start the necessary reorientation. Further steps should follow, and should also be accompanied by organisational changes to the research system and to innovation policies.

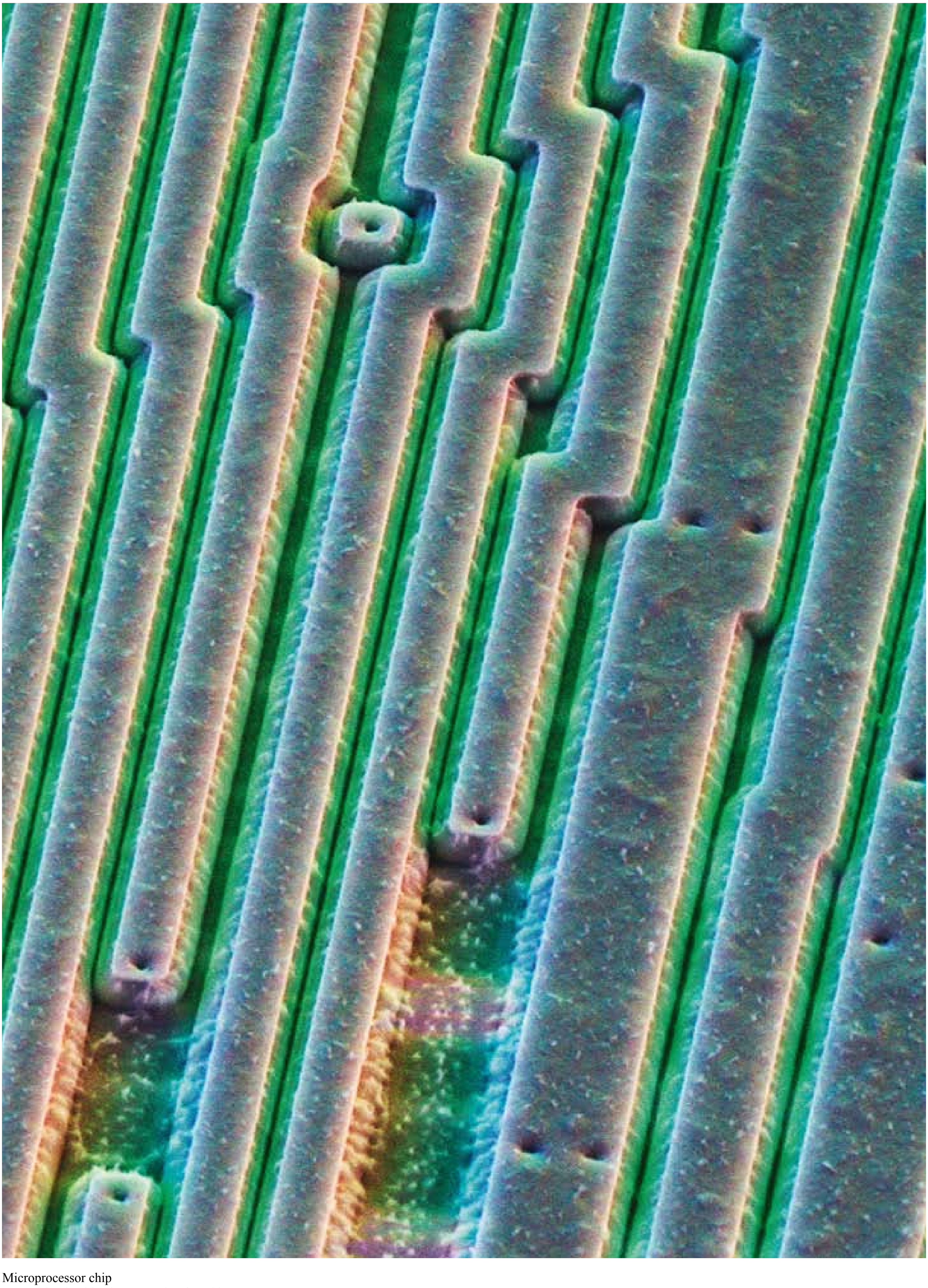
In order to be able to evaluate and control these structural changes to the R&I system, a detailed analysis of the research system and its most important components is required. This section of the report will first consider the industrial R&D system, followed by an assessment of the structure of the public science system.

The research and innovation system of the private sector

Germany has a well-developed and effective industrial R&D system, which concentrates on the most



Component with silicon nanowire



Microprocessor chip

BOX 09

Indicators for the evaluation of the R&I system

Important indicators for the analysis of the national research and innovation systems are the R&D expenditure and the level of R&D employment. For the private sector, innovation expenditure is also registered, which as a rule is much higher than the R&D expenditure.[33] The performance of the private sector is judged on the basis of data relating to growth, structural changes, exports, patent position, etc. The public science systems is assessed by analysing research results such as publications, patents, citations and technology transfer.

Total R&D expenditures in Germany in 2008 amounted to some EUR 66 billion.[34] According to estimates of the Stifterverband there was a slight increase in R&D expenditure as a proportion of the gross domestic product to 2.6 percent (2007: 2.54 percent). At the end of 2007, there were a total of 506 000 R&D employees in Germany, of which 185 000 were scientists.

In recent years, the German private sector has increased the proportion of GDP spent on R&D continually from 1.54 percent in 1998 to 1.78 percent in 2007. In contrast, the proportion spent by the state sector has remained almost constant (0.72 percent 1998 and 0.76 percent 2007). Thus the increase in German R&D intensity from 2.27 percent of GDP in 1998 to 2.54 percent in 2007 is attributable almost exclusively to the private sector. In 2007, 70 percent of national R&D expenditure in Germany comes from the private sector and 30 percent from the public sector, of which 16 percent is attributed to universities and 14 percent to non-university research institutions. In few other countries does the private sector finance a higher proportion.[35] However, in recent years the expansion of R&D expenditure in Germany's private sector has been below average in an international comparison.

important export industries.[36] In 2008 the private sector spent a total of EUR 57.3 billion on R&D – and despite the start of the economic crisis in autumn 2008 this represented an increase of 7.2 percent over the R&D expenditure in 2007.

At the end of 2008, the private sector had 333 000 employees working on research and development.[37] According to company planning data, the expenditure on R&D in 2009 was to be maintained at the previous year's level.[38] However, it is not yet clear whether these plans could be adhered to. By 2010 at the latest it is expected that the companies will reduce their R&D budgets and projects will be stretched or cuts made.[39]

The global financial and economic crisis led in almost all industrialised countries to marked declines in industrial R&D expenditure. Private R&D investments are sensitive to economic changes, but the patterns differ considerably between countries and sectors. Data from previous economic cycles shows that German companies react less to economic downturns than companies in other countries.[40] However, they are also less dynamic when it comes to expanding during economic booms. In the upturn from 2004 to 2007, private sector R&D expenditure in the OECD countries increased by 28 percent; in the German private sector over the same period the increase was only twelve percent.[41]

The typical German growth pattern is characterised by strong performance in the high-value technologies and at the same time deficits in the important cutting-edge technologies. Private sector R&D expenditure remains concentrated on the manufacturing sector and here mainly a few sectors which are traditionally regarded as Germany's main export industries: the automotive sector (34.9 percent), electrical engineering (16.3 percent), chemicals and pharmaceuticals (13.8 percent), and mechanical engineering (10.7 percent). In these R&D-intensive sectors, innovation expenditure in 2008 amounted to EUR 47 billion (Table 1).

In contrast, the structural shift towards services and the expansion of growth fields of cutting-edge technology has progressed less in Germany than in other highly-developed OECD countries. However, 16.9 percent of private sector innovation expenditures meanwhile go on knowledge-intensive services, in particular IT-services and telecommunications (8.7 percent), financial services (3.2 percent), and technological services.

TAB 01 **R&D expenditure and innovation expenditure in the German economy 2008**[42]

Sector	WZ 2008	R&D expenditure EUR billion*	% of total expenditure on R&D	Innovation expenditure EUR billion	% of total expenditure on innovation
Chemistry / Pharmaceuticals	20–21	8.6	13.8	12.6	9.8
Electrical engineering	26–27	10.1	16.3	16.2	12.7
Mechanical engineering	28	6.6	10.7	12.0	9.3
Motor vehicles	29–30	21.7	34.9	36.5	28.5
Research intensive industry	20–21. 26–30	47.0	75.7	77.2	60.3
Other industry	5–19. 22–25. 31–33. 35–39	5.9	9.5	21.1	16.4
Media services	58–60 (ohne 18)	0.3	0.5	1.9	1.5
IT / Telecommunications	61–63	4.7	7.6	11.1	8.7
Financial services	64–66	1.2	2.0	4.0	3.2
Consultancy / Advertising	69–70. 73	0.9	1.4	1.9	1.4
Technical / R&D services	71–72	1.6	2.5	2.7	2.1
Knowledge intensive services	58–66. 69–73	8.6	13.9	21.6	16.9
Other services	46. 49–53. 74. 78–82	0.6	1.0	8.2	6.4
Total		**62.0**	**100.0**	**128.1**	**100.0**

* The Mannheim Innovation panel does not register R&D expenditure in the same way as the science statistics of the Stifterverband. Source: ZEW (2010). Mannheim Innovation Panel 2009.

Lack of dynamics in the cutting-edge technology sector

In the manufacturing sector in Germany, R&D is concentrated on branches with rather moderate growth and medium R&D intensities. Industries which have seen a particularly strong worldwide expansion of R&D in recent years, e.g. the pharmaceutical industry and biotechnology, information and communications technology, and optoelectronics, are less strongly represented in Germany. German manufacturing companies are going through a process of significant structural change internally, in particular through the assimilation of R&D-intensive technologies and the expansion of new fields of business.
In contrast, in many other comparison countries there has been a marked expansion of new manufacturing sectors and especially R&D-intensive cutting-edge technologies. In particular in Sweden, Finland, Denmark and Austria this has led to a significantly higher increase in the average R&D rate than in Germany.[43]

The economic structure in Germany has not been developed in favour of sectors with a particularly high R&D intensity. Instead, the sectors which have grown in Germany are those which have shown a constant or even declining global R&D intensity. It is highly risky to concentrate on motor vehicle construction – which accounted for no less than 35 percent of private sector R&D expenditure. This can be seen clearly in the current economic crisis, in which the pillars of the industrial R&D system – automotive sector, mechanical engineering, and electrical engineering – have been hit particularly hard. The concentration on high-value technologies coupled with the neglect of cutting-edge technology has a negative effect on the innovation dynamics in Germany. Growth fields in cutting-edge technology markets and in knowledge-intensive services are not accessed quickly enough.

In the period from 2002 to 2007, there was a decline in the proportion of companies with an R&D intensity at the level of cutting-edge technologies. The proportion of companies with R&D intensity of more than 7 percent fell from about 6 percent (2002 to 2004) to some 4 percent in the period 2005 to 2007. Between 2003 and 2007, the R&D expenditure of the largest global companies active in pharmaceuticals and biotechnology rose by 33 percent, in IT-hardware by 24 percent, and in software and computer services by 28 percent. In this period, worldwide R&D expenditure in the automotive industry only increased by nine percent and in the chemical industry by 1.5 percent. Only in mechanical engineering (+24 percent) and in medical technology (+32 percent) did German companies participate in expanding the worldwide R&D capacities.

The globalisation of R&D continues

German companies are strongly integrated in the R&D globalisation process and they considerably expanded their involvement in foreign countries between 1998 and 2008. In addition, foreign multinationals are also increasingly present with R&D in Germany, so that these two effects balance each other out. However, here too the R&D location Germany profits more from its traditionally strong sectors, whereas R&D expenditures in cutting-edge technology mostly pass Germany by. For example, American companies concentrate their foreign R&D-investments in the sectors pharmaceuticals, communications technology and semiconductors mainly in Asia and a few European countries such as Great Britain and Ireland or Scandinavia. It is only in the classic fields of German industry (automotive sector, mechanical engineering, chemistry) that they continue to carry out R&D in Germany. The investment profiles of companies from other countries are similar.[44]

Leading German companies are increasingly making R&D investments in other countries, in part in a complementary fashion so that the Germany headquarters are strengthened. However, R&D investments in other countries are increasingly being made as a substitute for R&D involvement in Germany.[45] It is particularly striking that the expansion of R&D activities of German companies in the dynamic sectors is mainly taking place in other countries. This can lead to the abandonment of strategically important sectors in Germany. There have been such negative developments in particular in the pharmaceutical industry and biotechnology as well as in semi-conductor technology and software development. For example, in the German pharmaceutical industry the proportion of R&D expenditure in foreign countries rose between 2003 and 2007 from 50.1 percent to 69.2 percent, in some cases involving particularly promising research, which is now only carried out in foreign R&D laboratories.[46] The trend in pharmaceuticals, biotechnology, medical engineering and software is to choose leading locations in North America, whereas in electronics, telecommunications and electrochemicals there is often a preference for Asia. This development will have longer-term implications for the innovation system in Germany, because it limits the effectiveness of the cooperation with public basic research and also impacts on the educational system. Shifting R&D in particularly dynamic sectors to other countries means losing important impulses for the cooperation between the research institutes at German universities and non-university research institutions. In addition there is the risk of losing important areas of business, which are able to offer valuable job opportunities for the highly qualified.[47]

Public research and science in an international comparison

Over the longer term, there has been a shift towards private R&D. Whereas 47 percent of R&D expenditure in the OECD in 1980 was state funded, this proportion fell successively to 28.1 percent in 2007. Between 1994 and 2000 only one sixth of the increase in R&D expenditure in the OECD countries came from governments, compared with three quarters provided by the private sector.[48] For a long time, Germany did not play a leading role in the development of public research. In particular the USA, the northern and southern European countries have increased state R&D expenditure more than Germany has. It is only since 2004 that the increase in Germany has been above the average for OECD countries.[49]

A strong public research infrastructure is very important and essential for securing the long term future of locations. Germany has now taken the necessary measures by increasing public funding for research. The public research system consists of universities und non-university research institutions (AUF). The two forms are complementary and make a wide range of contributions to research, education and knowledge transfer, and thus directly and indirectly to the innovative potential at the macroeconomic level. In the following, the Expert Commission considers in particular the division of responsibilities between the science institutions in Germany, the forms of cooperation with the private sector and the effectiveness and efficiency of the processes. The analysis focuses first on non-university research and its internal structures.

The structure of public research

The total research budget in the public sector amounts to EUR 19.8 billion (2008). Of this, EUR 10.7 billion go to the universities and EUR 9.1 billion towards non-university research. At the end of 2008, the two sectors together were employing 189 000 R&D personnel (expressed in full-time equivalents), of which 108 000 worked at universities, and 81 000 at non-university institutions.[50]
The German science system has fairly unchanging basic structures, in contrast to other industrialised countries. This can represent an advantage in terms of the continuity of research, but when it comes to flexibility and innovation dynamics there are also disadvantages. It is remarkable that the R&D expenditure of the public science sector as a proportion of gross domestic product has been stable since 1981 at about 0.75 percent. In particular the distribution between universities (0.4 percent) and non-university research (0.35 percent) has remained largely constant over that period.

In the OECD countries, non-university research as a proportion of GDP fell between 1995 and 2007 from 0.3 percent to 0.25 percent.[51] At the same time, the proportion of the research in the university sector increased from 0.33 percent to 0.38 percent of GDP. Other countries also made significant reductions to non-university institutional research relative to GDP in this period, e.g. in the USA from 0.3 percent to 0.25 percent, in Great Britain from 0.28 percent to 0.16 percent, in France from 0.48 percent to 0.34 percent, and in Canada from 0.24 percent to 0.19 percent.

The expansion of the education system and university research has played a key role in many OECD countries since 1995 and even more so after 2000. Average expenditure on university research as a proportion of GDP by OECD countries increased from 0.33 percent 1995 to 0.38 percent 2007, e.g. in the USA from 0.31 percent to 0.36 percent, in Great Britain from 0.37 percent to 0.44 percent. The developments in Canada (increase from 0.46 percent to 0.63 percent) and Korea (from 0.19 percent to 0.37 percent) are particularly remarkable. Germany has not matched this expansion of university research in combination with the consolidation of non-university research structures. Significantly, there was a significant expansion of education over the period in question, so that presumable increased teaching obligations displaced research in the time budgets of university staff. Attention should therefore be paid in coming years to a balanced expansion of education and research, and to improvements in the structure of university research.

Setting priorities in the system of non-university research

Germany has a highly-developed system of research with various independent science organisations with very different remits. In 2007, the four most important organisations employed 56 percent of the scientists of non-university research institutions, namely the Helmholtz Association (HGF) 22 percent, Fraunhofer Society (FhG) 12 percent, the Max Planck Society (MPG) 11 percent, and the Leibniz Association (WGL) 11 percent. Together they account for 74 percent of the research expenditure in the non-university research sector. The following institutions receive about a quarter of the budget for non-university research and employ 44 percent of the personnel: Federal department research institutions 16 percent, Laender institutions 7 percent, academies, scientific libraries and museums 6 percent, and other institutions 15 percent. The other institutions consist of 400 publicly-funded non-profit organisations with widely varying remits in science, research, and technology transfer.

Such organisational and institutional differentiation can easily lead to inefficient duplication and inadequate strategic coherence. Over many years, the institutes of the Fraunhofer Society (FhG) or the Max Planck Society (MPG) have developed a clear research profile and have established an excellent international reputation, but the same cannot be said for all institutions. The institutions organised within Helmholtz Association and the Leibniz Association since the 1990s have meanwhile gone through a transformation process, which has led in many cases to an increase in scientific performance. Many institutes and research sectors in both associations are of excellent quality.

Structure of public research in Germany 2007

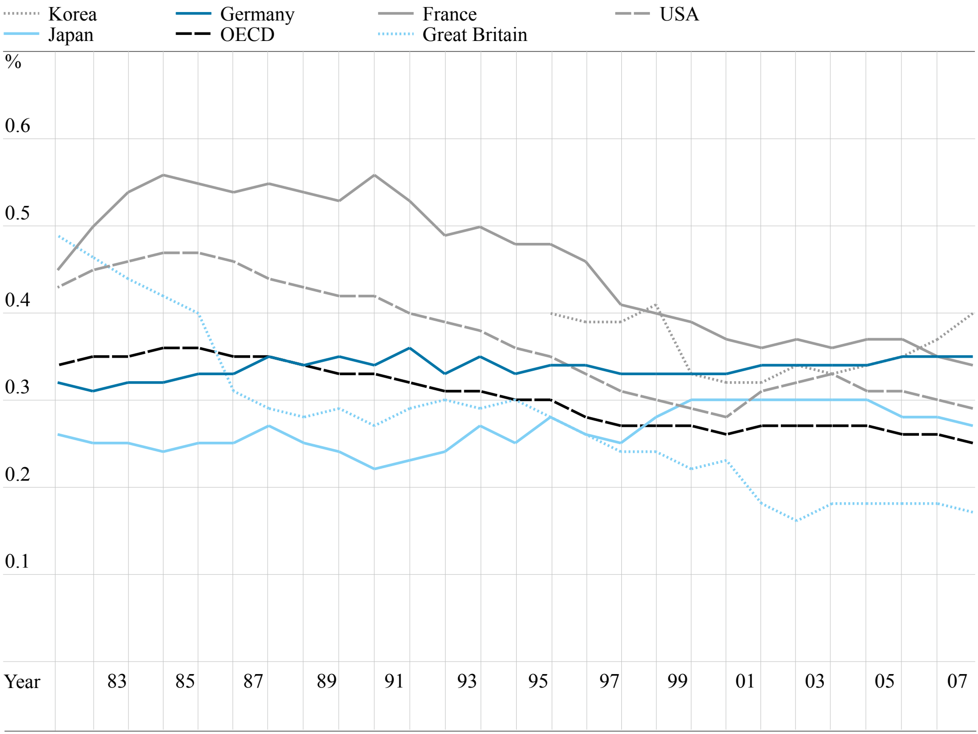
TAB 02

Institution	Research expenditure in Mio. Euro	Research personnel (full-time equivalence)	of which scientists
Non-university research	**8 540**	**80 664**	**43 561**
Max Planck Society (MPG)	1 290	11 785	5 996
Fraunhofer Society (FhG)	1 319	10 519	6 667
Helmholtz Association (HGF)	2 740	23 283	12 190
Leibniz Association (WGL)	966	9 699	5 480
Federal research institutions (BFE)	681	8 319	3 675
Land and communal research institutions	218	2 990	1 354
Other research institutions	1 002	10 930	7 138
Scientific libraries and museums	325	3 119	1 062
Universities	**10 000**	**103 953**	**72 985**
Public research – Total	**18 540**	**184 597**	**116 546**

Source: Statistical Federal Agency. Statistical Federal Yearbook 2009.

Survey responses for the importance of tasks for non-university research institutions in Germany

FIG 01



Source: OECD (2009a). Calculations by ZEW.

However, the research profiles and the remits of these research organisations are much more heterogeneous than the FhG and the MPG.

In the past, reference was made to pillars supporting the German research and science system.[52] Every scientific organisation, it was argued, pursued an independent mission, e.g. basic research at the MPG, or applied research at the FhG. The cooperation was particularly intensive between institutes belonging to the same science organisation, but was comparatively weak between the various science organisations.

The Expert Commission has commissioned a study to examine this claim empirically for the first time. The study shows that in recent years there has been an increase in new and innovative forms of cooperation between the various types of science organisations. Almost all non-university research institutions cooperate with universities, and in the course of the Excellence Initiative various institutions have been integrated in research networks. Common forms of cooperation include joint research projects (72 percent), university chairs for personnel (42 percent), and the joint supervision of postgraduate students (44 percent). Meanwhile, cooperation with institutions from other organisations carrying out non-university research is more common than cooperation with institutions within the same organisation.[53]

Table 3 shows the tasks to which the various non-university research institutions attach the greatest importance. The Max Planck Institutes are clearly focused on basic research, whereas the Fraunhofer Society primarily addresses applied research and knowledge transfer. In contrast, the priorities of the institutions within the Helmholtz Association and the Leibniz Association and also in the Federal departments are much more heterogeneous. The Helmholtz Association is the largest science organisation in Germany with a total of 23 300 personnel and R&D expenditure of EUR 2.7 billion, and many of the HGF institutes achieve commendable research results. The Association also establishes a bridge between basic research and applied research. In addition, the original remit of the HGF is also to organise the investigation of systems using large-scale equipment and extensive scientific infrastructure. The Expert Commission feels that a clearer distinction should be made between those HGF institutions, which are still carrying out large-scale research as originally intended and the others, which now pursue a very different mission. Strategies should be developed for both types of HGF institutions, and they must establish a profile which differentiates them more clearly from other science organisations. In particular the situation of the German Aerospace Centre (DLR) within the HGF should be analysed in detail in terms of research strategies.

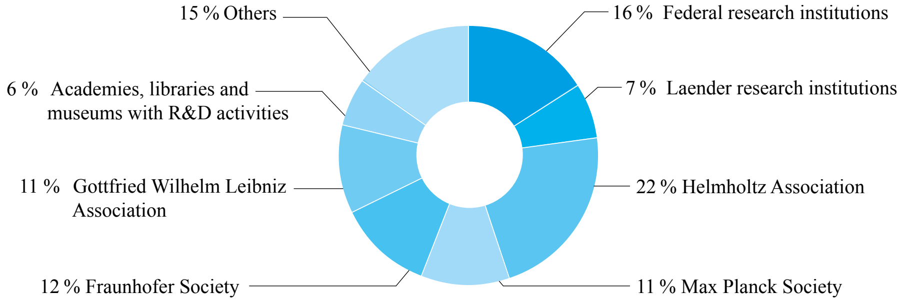
The Leibniz Association (WGL) is an umbrella organisation of 86 legally independent institutions, including not only research institutes but also institutions of the scientific-cultural infrastructure. The WGL employs 9 700 R&D personnel and has an R&D budget of about EUR 1 billion. Its remit includes basic research and applied research, as well as performances relating to information and documentation, knowledge transfer, further and continuous training, and consultancy services for public agencies. The coordination of individual research institutions in the WGL only involves sharing information; the central organisation does not intervene in decisions of the individual institutes. The widely varying remits of the individual institutions within the WGL and the special form of joint funding (50 percent from the Federal Government, 40 percent from the local federal state, and 10 percent from a shared fund of all Laender) suggest that there will be difficult structural adaptations in the coming years.[54]

A considerable proportion of public R&D expenditure goes towards Federal Government departments and research institutions of the Laender and local authorities. The Federal departmental research institutions, allocated to nine ministries, employ a total of 8 300 personnel and have a research budget of EUR 680 million (2007). These research institutions have been evaluated in recent years, although without calling into question the system as a whole. The Commission recommends that the Wissenschaftsrat (German Council of Science and Humanities) should draw relevant conclusions from the evaluation of the government department research institutions. It is necessary to note which tasks are of national importance, and which research activities are very specifically related to only one government department. Institutions, which do not meet these criteria, i.e. which are not carrying out work of national importance and are carrying out general research work, which is rather interdepartmental, should either be integrated into the existing system of science

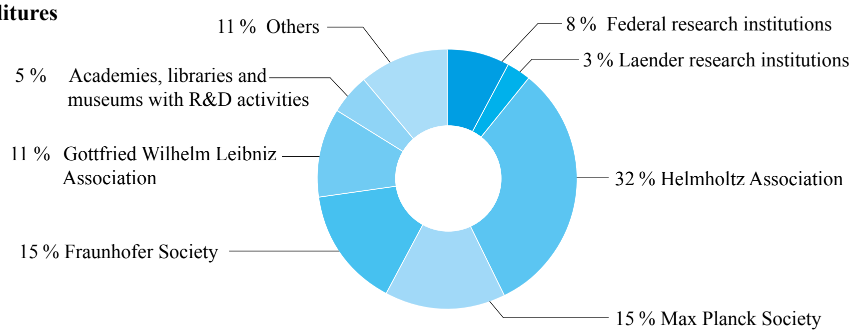
R&D expenditure

FIG 02

Scientists



Expenditures



Source: Statistical Federal Agency, Series 14, Row 3.6 (various years). Calculations by ZEW.

Survey responses for the importance of tasks for non-university research institutions in Germany

TAB 03

	Total	MPG	FhG	HGF	WGL	BFE	Others
Basic research	**44**	100	9	46	62	7	33
Applied research	**57**	3	91	57	48	74	67
Technical development	**18**	3	46	26	6	7	23
Measurements, Tests, Standards /Certification	**11**	0	17	6	6	26	15
Information and documentation	**11**	3	3	3	23	22	8
Training, Further training	**16**	22	3	34	19	7	10
Provision of scientific infrastructure	**15**	6	11	37	13	15	8
Knowledge /technology transfer to companies	**26**	3	57	31	12	7	40
Knowledge transfer to the public	**15**	19	0	14	23	15	15
Advice for public bodies	**20**	3	9	17	19	78	10
Public tasks	**13**	3	3	9	10	56	10

% of non-university organisations in a group (abbreviations as in Table 2) which chose the top response level for the five-level Likert items (multiple responses possible). Source: Polt et al. (2010: Tab. 002 – 004). ZEW, survey 2009. Calculations by ZEW.

organisations, restructured in the medium-term, or closed down. The Federal Government formulated guidelines in 2007 for modern departmental research, which suggested valuable improvements against the background of the previous division of responsibilities and allocation to departments.[55]
On the basis of the new recommendations presented by the Science Council in Spring 2010 a reorganisation of departmental research should be considered both at the Federal Government level and at Laender level. The necessary structural improvements and the recommendations of the Science Council should be fully implemented.[56]

Research and innovation performance of the individual science organisations

The priorities for non-university research outlined above, and often referred to internationally as the "German model", result in various strategies and research performances. Patents applications and publication outputs for the four major science organisations and the universities were analysed for the period 1994 to 2006. At one end of the spectrum, the Fraunhofer Institutes have a large number of patents and a comparatively low publication output. They had more than 70 patent applications per 1 000 scientists annually in the period 2004 to 2006, by far the highest patent productivity.[57] But they only achieved 0.15 SCI publications per scientist each year.

The Max Planck Institutes, which concentrate more on basic research and scientific excellence, report 1.35 SCI publications per scientist and year. Less emphasis is placed on patenting and commercial exploitation, with the result that they have only 12 patent applications per 1 000 scientists annually. Between these two extremes are the Helmholtz institutions, the Leibniz institutions, and the universities. No comparable information about patents and publications is available for government department research and the other institutions.[58]

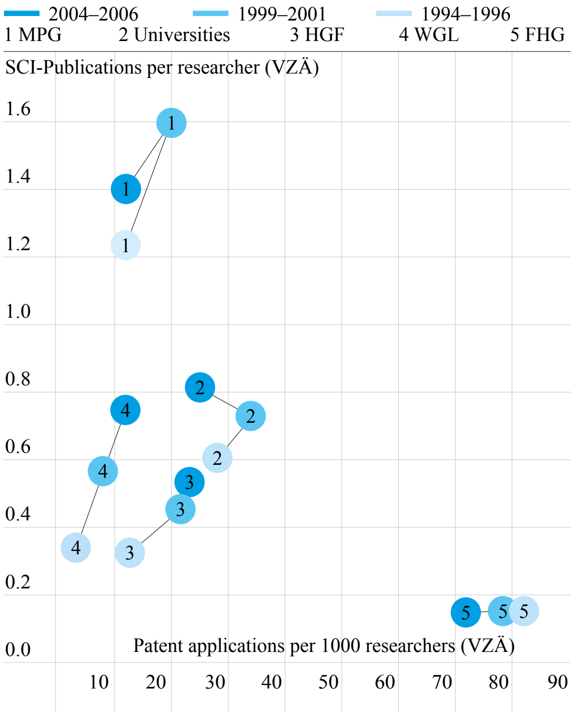
Particularly interesting is the development over time of the research achievements and the light this casts on the changing research strategies. Starting from a low level of publication activity in comparison with MPG, and a low level of patent applications in comparison with FhG, the Helmholtz centres and Leibniz institutes have made marked improvements for both indicators. Between 1994–1995 and 2004–2005, the Leibniz institutes achieved on average an eight percent growth rate in the publication output per scientist; patent applications per scientist increased by 15 percent. For the Helmholtz centres the corresponding growth rates were five and six percent, respectively. These analyses commissioned by the Expert Commission highlight that concentrating only a few indicators such as SCI publications and patent output can lead to the wrong incentives being given.[59] In particular achievements in technology transfers are neglected. Insufficient attention has been paid to this aspect in the past when evaluating institutions.[60]

Project funding and full cost funding

For public research in the non-university research institutions and universities, the structure of the funding plays a crucial role. There is a tendency for a greater weighting to be attached to the project funding relative to the basic funding. The Expert Commission welcomes this, because it encourages competition in R&I. However, project funding requires

Changes in publication and patent intensity of major science organisations and universities[61]

FIG 03



Abbreviations: MPG, HGF, WGL, FhG: see Table 2 or Reference section
Sources: Fraunhofer ISI, evaluation from SCISEARCH (STN) and PATSTAT (EPO). BMBF (2008). StaBA: Series 14 (3.6), 11 (4.4), 22 (4.5) OECD (2009a). Calculations by ZEW.

uniform rules, in particular concerning the accounting of indirect costs. In view of the new European framework conditions and the changed payment procedures of individual project funders, there is a trend towards funding projects on the basis of full costs.

Full cost funding would favour fair competition for funds between the various research institutions and thus increase the efficiency of fund allocation. The rules for accounting for indirect costs are still varied. This can lead to disadvantages for research institutions, which already include relatively high indirect costs, but which face competition from institutions, which only include their direct costs. In contrast, this regulation is disadvantageous for those institutions, in particular the universities, which are only able to include some indirect costs if any, and who frequently have to subsidise the projects from their basic funding.

The coalition agreement between CDU, CSU and FDP envisages considering the introduction of a flat sum in the project support from the Federal Government, like that provided by DFG. It consists of 20 percent of the relevant direct project expenditure and covers the related indirect, additional and variable project expenditures. The Expert Commission expressly approves of the introduction of such a programme flat sum. However, this should only be a first step on the way to full-cost funding.

Interaction between public research and industrial innovation

Effective cooperation between public research and industrial R&D is of key importance in a knowledge-economy. In many areas, Germany has reliable instruments and transfer channels, in particular where it has been possible to establish long-lasting relationships between companies and training and science institutions. There are signs of implementation deficits and transfer breakdowns for younger science disciplines, which have their own dynamics. This is reinforced if there are not enough active companies in the national setting to ensure the implementation. Worldwide innovation in many young disciplines is characterised by the formation of many new enterprises. However, in Germany this dynamic is inadequately developed due to the inadequate framework conditions and the lack of focus on cutting-edge technologies.

Mixed situation for knowledge and technology transfer

The following characteristics favour the successful cooperation between research und industrial innovation in Germany: advanced technology, average R&D intensity, German engineering traditions, production orientation, high quality, low price sensibility and well-established manufacturing structures. On the other hand, there are marked transfer deficits in those areas, which are characterised by: cutting-edge technology, high R&D intensity, new science disciplines, which are not yet established in Germany, entrepreneurship, services orientation, need for cost efficiency, and extremely strong international competition.

Cooperation between public research and the business sector works best where the fields of cooperation and the R&D topics of both sides fit well together and projects are synchronised. However, there are noticeable differences between the R&D portfolios of German companies and the research portfolios in the public sector. Whereas industrial R&D efforts are concentrated on a few manufacturing sectors, and mainly on the development of incremental adaptations, the portfolio of public research covers a relatively broad range of topics from cutting-edge research and high technology.

Promising lines of cutting-edge research are pursued by many research-intensive non-university institutions and the universities in Germany. However, they do not always place the emphasis on transfer possibilities or subsequent commercialisation. The research strategies and incentives structures in many institutions result in scientists being more interested in scientific breakthroughs, publications and increasing their reputation in the scientific community. However, the results obtained in cutting-edge research can only be applied and developed to a limited extent if there is no industrial utilisation domestically. In important fields of information and communications technology, or biotechnology and genetics there are few German companies working to effectively transfer developments into marketable products. R&D-intensive companies in fields such as vehicle manufacturing, chemistry, and mechanical engineering make frequent use of the latest technological advances. However, they mainly use their research results internally. Companies from areas of cutting-edge technology, e.g. pharmaceuticals and biotechnology, network and Internet technology tend to stimulate the innovation process more, but they are less well represented in Germany.

Greater efforts are needed to improve knowledge and technology transfer

Increased efforts are needed both by institutions carrying out basic research and in companies in order to overcome the regrettable deficits in implementation. The private sector must open up promising fields, which are compatible with the specific strengths of German research. These should be promoted by increased third-party funding, the establishment of new foundations and institutes, and new models for cooperation between companies and universities or research institutions. There are growing numbers of examples of this, e.g. at the LMU Munich, RWTH Aachen, and the universities in Darmstadt, Heidelberg und Oldenburg.[62]

Knowledge and technology transfer works very well where manufacturing companies and public research institutions are working in complementary fields and can exchange information on the basis of well-established personal contacts. However, all too many research projects and institutes find no potential industrial partners in their vicinity and prefer to draw on the attractive funding from public sector sources. In addition, these institutes do not have the necessary incentive mechanisms for cooperation with the private sector, or they lack sufficient experience. In particular the institutes of the Fraunhofer Society and the universities cooperate closely with the private sector.

For non-university research institutions, the ability and willingness to engage in transfers depends primarily on the priorities that they set themselves and the personnel management. There are considerable differences between institutions, with some even showing “transfer abstinence”. The key assessment criteria for MPG institutes are excellence and the numbers of publications, as well as training young scientists. In HGF and WGL, the technology transfer mechanisms are not structured clearly enough, which is the result of the greater heterogeneity of these institutions. In the course of the reorientation over the past ten years and in the course of evaluations, both HGF and WGL have attached increasing importance to scientific excellence. The excellence of publications was cited as the most important point for the assessment of performance at HGF in 63 percent of cases (WGL 62 percent), but knowledge and technology transfer to companies was only cited in 14 percent of cases (WGL 13 percent).[63] Scientific excellence should not be abandoned as a goal and evaluation criterion, but in the coming years increased support should be given to cooperation between the private sector and science, and to the willingness to engage in knowledge and technology transfer. This requires measures at the level of control mechanisms, governance, and human resources management, e.g. further training and new career models for scientists.

Governance of the German R&I system

Successful innovation requires the cooperation between various actors from basic research, the education system, and the private and public sectors, as well as legislation and regulations. A “cohesive and uniform innovation policy” should support the close links between the actors and thus ensure the development at the national level of a more effective innovation value chain in specific areas of promise.

In many countries, responsibilities for research and innovation policies develop over time, and as a result are often distributed between several ministries, which restricts the effectiveness of the process chain. As in many other countries, research and innovation policies in Germany are in the main the responsibility of two ministries, the Federal Ministry for Education and Research (BMBF), and the Federal Ministry for Economics and Technology (BMWi). This division of responsibilities can make it more difficult in some cases to implement a “cohesive and uniform innovation policy” and to establish a bridge between basic research and innovation in the private sector.

In addition to the coordination problems between science and economics departments, the governance of the R&I system in Germany has a series of characteristics, which also restrict the efficiency of policy making. For example, numerous departmental research institutions and federal agencies are also allocated to other ministries, in particular the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), the Federal Ministry of Health (BMG), the Federal Ministry for the Environment, Nature Conservation and Reactor Safety (BMU), the Federal Ministry of Transport, Construction and Urban Affairs (BMVBS), and the Federal Ministry of Defence (BMVg). In important fields of innovation, e.g. electromobility, energy research and materials research, this makes it more difficult to follow an effective national innovation strategy.

An example is materials research, which has been supported since 1984 by consecutive programmes at Federal Government and Laender levels as well as by the EU Commission. Over this period, some excellent research results have been achieved in Germany for important new materials (e.g. structural ceramics, or carbon fibre composites). However, there is often inadequate commercial implementation and a continuous value-creation chain is missing. This is due in part to a failure of coordination, made worse by excessive decentralisation and overlapping in the provision of research support. The transition from research projects to independent entrepreneurial structures is not pursued by the actors involved, among other things because there are numerous follow-up programmes providing support for R&D projects, distributed among several ministries, various project funding institutions and Federal States. For example, projects concerning new materials in aeroplanes fall under the responsibility of the Ministry for Economics and in part the Ministry of Defence. But very similar projects in the automotive sector are classified under mobility and are allocated to the Federal Ministry of Transport. In addition, important complementary developments of processing technologies are covered by the WING programme of the Federal Ministry for Education and Research. Many agencies are involved along this "support chain" and some Laender have also set up their own ambitious materials research programmes. It is quite common for projects to pass along the stages of this support chain, without the research results being transferred to marketable products. Between 2000 and 2008, material researchers were able to obtain follow-up funding in the nanotechnology sector. Currently, funding opportunities for materials projects are being opened up by new initiatives in electromobility and light-weight construction, without rigorous examination of why very similar projects failed in the past (e.g. in the automotive industry).[64]

The High Tech Strategy adopted by the Federal Government was an important step towards overcoming this coordination problem. However, the implementation of the strategy was the responsibility of the individual ministries and the associated project funding institutions and advisory bodies. So far, little use has been made of the opportunities for improved cooperation between the ministries offered by the High Tech Strategy.

In contrast to many other countries, Germany does not yet have a powerful body to coordinate research and innovation policies at the national level and to generate the necessary coherence between government ministries. This is the role played by the *National Science and Technology Council* in the USA, the *Council for Science and Technology Policy* in Japan, or the *Council for Science and Technology Policy* in Korea. The existing institutions in Germany, such as the Science and Industry Research Union or the Council for Innovation and Growth, do not have a comparably broad remit. The Federal Government has important advisory bodies such as the Research Union, the German Academy of Science and Engineering acatech and the Commission of Experts for Research and Innovation, but they do not have clearly separate remits. The Expert Commission feels that Germany should also have a body with high-ranking representatives from business, science and politics to formulate guidelines for research and innovation policies and to supervise their implementation. This should report directly to the Federal Chancellery and have full authority and resources in order to implement the measures needed to increase the effectiveness of the R&I policies.

In other countries, and at the EU level, innovation agencies have been adopted. In Germany, however, the model of project funding institutions predominates, which has its advantages but which also leads to further departmentalisation and individual dynamics. Programmes are often prolonged, and can

continue for decades. The established organisational structure of government departments, project funding institutions and research institutions explains in part why there has so far not been a strategic reorientation of innovation policies.[65]
A typical dilemma for Germany is due to the twin-track nature of research and innovation policies at the level of the Federal Government and the Laender. The research at universities is mainly the responsibility of the Laender, whereas the non-university research institutions mostly receive funding from federal bodies and fall under their responsibility. Innovation policy and support programmes are implemented in parallel at federal government and Laender levels, in part in overlapping areas, but without the necessary coordination and focussing. Germany can and should urgently reform the excessive federal structure of education, research und innovation policy in order to achieve a higher ranking among the leading innovative countries.

Conclusions and recommendations

The German economy can only compete internationally if it successfully implements innovations. A key condition for this is the systematic increase of public R&D expenditure and private sector expenditure on innovation. The revised High Tech Strategy must provide additional impulses for the private sector to make further targeted investments in research and innovation. The German private sector should increase the proportion of their gross value added spent on R&D. Policy-makers are called on to support this by establishing innovation-friendly framework conditions.

Retain the three percent target – define interim targets

In the course of the current Bundestag through to 2013, efforts should be made to steadily increase R&D both in the private and public sectors. The three percent target of the Federal Government can only be reached in five to ten years time. In view of the financial and economic crisis a more realistic figure in the order of 2.7 to 2.8 percent should be taken as an interim target. The Federal Government and the Laender should set a good example and increase public expenditure on science and R&D to a steady 0.8 percent of gross domestic product.

Expanding cutting-edge technology

Structural economic changes and the further increase of R&D intensities should be a declared aim. This requires a targeted expansion of cutting-edge technology, because in the longer term, Germany cannot rely solely on high-value technologies and leave the cutting-edge technology to other countries. Steps must be taken to expand segments of cutting-edge technology in which a comparative advantage can be secured globally. Investments should be avoided in fields, which are subject to international subsidy wars. Germany cannot afford to invest public funds in areas of applied research, in which there is no realistic chance for private companies to take up the results and contribute to value creation in Germany.

Expanding knowledge-intensive services

Germany still has some catching up to do in many areas of services innovation. The Expert Commission recommends expanding knowledge-intensive services (services designed in Germany) where these are complementary to existing focal points in the economy. This requires support strategies, which are specifically tailored to suit the innovation processes in the services sector.

Increased targeting of the High Tech Strategy

The High Tech Strategy of the Federal Government has sent out an important signal about the importance of science, research und innovation. However, the limited budget was spread across too many fields of technology, which had played an important role in past Federal Government policies. The High Tech Strategy should concentrate on a maximum of ten fields of technology. This involves harmonising these fields with those identified in the foresight process and with the investment priorities in the private sector.

Further optimisation of non-university research

The distribution of funds and the “division of areas of specialisation” between the various scientific institutions should not be regarded as unchangeable. This applies in particular for the departmental research of the Federal Government and Laender. Structural reforms are necessary in order to improve the effectiveness of science organisations. The system of non-university research should be further optimised. In the coming years, particular attention should be paid to science organisations with internal heterogeneity and also in part duplicated research activity, in order to optimise structures and to highlight the specific contributions to Germany's innovation system.

Knowledge and technology transfer as a priority

Knowledge and technology transfer (WTT) from non-university research and the universities should be expanded as a priority. This goal must not be neglected in the justifiable pursuit of scientific excellence, as could be observed in various organisations in recent years.[66]
In particular the governance and the management and incentive structures of many research institutions are in need of further improvements. Suitable lessons should be drawn from the positive experience in many fields in Germany. This should stimulate sustainable improvements in other institutes and science organisations. New models are needed for cooperation between research institutions and the business sector as well as between the various science organisations. This will require the systematic evaluation of the experience gained so far in Germany. At the same time it is necessary to learn from the application of comparable models in other countries and to develop suitable benchmarks.

Improving research and teaching at universities

In future, research at universities must also be strengthened considerably. The Expert Commission recommends developing new models for cooperation between universities and companies in the form of Public Private Partnerships. New models are also needed for cooperation between universities and non-university research institutions along the lines of the existing developments in Karlsruhe and Aachen / Jülich. Universities are the key element for the development of a continuous Education – Research – Innovation chain. The combination of research and graduate training in Master's and PhD courses is the domain of the universities and should be strengthened further. This implies also that awarding PhDs should remain the exclusive priority of full universities. Joint graduate colleges involving universities and non-university research institutions should be developed further, but awarding academic degrees must not be entrusted to institutions outside the universities.

Increasing cost transparency, introducing full-cost funding

Effective research must be financed appropriately and supported with modern accounting and budget instruments. Project support by the Federal Government should in the short term include a lump-sum payment to cover indirect costs. In the medium-term it is appropriate to reimburse in full the costs of the research institutions carrying out third-party funded projects. Special adaptations are required for university research and appropriate infrastructure and cost-accounting systems must be introduced. This will strengthen third-party funded research and create a level playing field for the various science organisations. However, it must not lead to the Laender cutting the basic funding for the universities.

Full financial responsibility for universities

In order to develop infrastructure and establish the accountability of indirect costs it will be necessary in the longer term to overcome the lack of transparency in the division of ownership rights between universities and the responsible Federal State. This applies in particular for the ownership and rights of disposal regarding land, real estate and intellectual property. In the USA, the top universities are particularly strong because they hold property and patent portfolios, and are supported by rich foundations. In Germany, reforms have been introduced in North Rhine-Westphalia and Hesse to transfer real estate to universities. After evaluation of the experience made, new models should be developed for capitalisation and the expansion of foundations along the lines of the American model.