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ERAWATCH Country Report 2008
An assessment of research system and policies

Germany

Jan Nill, Alexander Grablowitz

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Executive summary

Research-related policies aimed at increasing investment in knowledge and strengthening the innovation capacity of the EU economy are at the heart of the Lisbon Strategy. The strategy reflects this in guideline No. 7 of the Integrated Guidelines for Growth and Jobs which aims to increase and improve investment in research and development, in particular in the private sector.
To support the mutual learning process and the monitoring of Member States efforts, one task of ERAWATCH is to produce analytical country reports. The main objective is to characterise and assess the performance of national research systems and related policies in a structured manner that is comparable across countries. In order to do so, the system analysis focuses on key processes relevant for system performance. Four policy-relevant domains of the research system are distinguished, namely resource mobilisation, knowledge demand, knowledge production and knowledge circulation. This report is based on a synthesis of information from the ERAWATCH Research Inventory and other important available information sources.

Germany has a highly developed and well functioning research system, as the following overview of main strengths and weaknesses shows.

Domain	Challenge	Assessment of system strengths and weaknesses
Resource mobilisation	Justifying resource provision for research activities	Well established justification in terms of preserving economic competitiveness through S&T did not prevent declining share of R&D expenses in general budget
	Securing long-term investment in research	Stable mechanisms to ensure long-term research funding, but multi-level negotiations for increases are time-consuming and require political majorities difficult to achieve
	Dealing with barriers to private R&D investment	The two-thirds share of private R&D funding meets Lisbon objectives
	Providing qualified human resources	Functioning mechanisms for the provision of a strong human resource base for R&D with declining S&T graduate basis but increased attractiveness of research careers
Knowledge demand	Identifying the drivers of knowledge demand	Demand signals from classical industries well perceived by policies, but demand signals outside of these or international demand signals not well addressed
	Co-ordinating and channelling knowledge demands	Strong R&D programme basis enables a flexible response to changes in demand
	Monitoring demand fulfilment	Well established evaluation mechanisms
Knowledge production	Improving quality and excellence of knowledge production	Mechanisms in place to enhance scientific excellence of public research through DFG and Science Council. However, the rigidity of the public research system, which is strongly geared towards traditional scientific disciplines, makes it difficult to adapt to cross-cutting opportunities
	Improving exploitability of knowledge	Strong focus on research closely linked to the economy's strengths
Knowledge circulation	Facilitating circulation between different research sectors	High profile of knowledge circulation measures
	Profiting from international knowledge	Number of measures and institutions in place to ensure access to international knowledge
	Enhancing the absorptive capacity of knowledge users	Broad R&D base in the private sector ensuring good absorptive capacity, but weak dynamics with regard to new private research performers and S&T graduates

In each of the main domains there are strong system responses to the respective challenges. Very often the responses take the form of quite stable institutional arrangements, such as the role of the German Science Foundation and the German Science Council in enhancing quality and excellence of knowledge production, or the Fraunhofer Society and the AIF in enhancing knowledge circulation to the economic sector. Any remaining weaknesses are mostly related to the adaptation and enhancement of the changes being put in place, whether this is the extent of increases in financial resources or addressing signals of cross-cutting new demand and new scientific opportunities. They are partly a reflection of the strength of the established system responses.

The governance structure reflects the high level of development and the differentiated structure of the German research system. The only area in which system weaknesses are closely related to the governance structure as such is the complicated process whereby resource mobilisation is coordinated in a federal system with shared responsibilities.

The following table presents main opportunities and risks related to recent policy dynamics.

Domain	Main policy-related opportunities	Main policy-related risks
Resource mobilisation	- Increased volume of federal resource mobilisation through the "Six billion Euro programme"	- Public resource mobilisation, in particular at the Länder level, is insufficient to meet the Lisbon target - Private resource mobilisation might not respond to increased incentives to the extent anticipated
Knowledge demand	- More effective knowledge demand through better coordination between federal actors and more holistic approaches via the High-Tech Strategy	- It remains to be seen to which extent the new foresight process successfully addresses demand signals outside the classical technologies/sectors
Knowledge production	- Improved excellence and increased international attractiveness of public research enhanced by the Initiative for Excellence - Further strengthening of exploitability of knowledge by reinforced cluster approaches	-
Knowledge circulation	- Further improvement of the circulation of knowledge between sectors through new measures and governance mechanisms targeting co-operation between public research organisations and industry, - Internationalisation strategy provides framework for benefiting from international knowledge	- Policy measures too strongly oriented on knowledge circulation towards established firms

The table shows that recent policies since 2007 are to a large extent shaped by the implementation of major initiatives launched the years before: The Six Billion Euro programme, the High-Tech Strategy and the Initiative for Excellence address some of the main weaknesses of the German research system and hence help to create opportunities for its further evolution. Most aspects of the research-related Integrated Guideline of the Lisbon Strategy are addressed, from the 3% R&D intensity target, via the strengthening of centres of excellence and the reform of the public research

base to the improvement of co-operation between PRO and industry. Although there are now first experiences with implementation, the extent of the effects of recent policies remains to be seen. An important recent policy initiative is the internationalisation strategy. It responds to the internationalisation of knowledge production by mainly also following a "strengthening the strengths" approach.
Main policy-related risks are related to the domain of resource mobilisation, where despite considerable efforts at the level of federal Government, both public and private R&D funding seem still insufficient to meet the 3% target. And recent policy measures in the domain of knowledge circulation are only partially addressing weaknesses such as the seemingly stagnating absorptive capacity. It remains to be seen if the new central innovation programme for SMEs of which the first part was just launched will be able to make a difference in this respect.

The analysis of recent policies has also shown that, by and large, current German research policy priorities correspond to the strengths and weaknesses of the research system. As might be expected in highly developed research systems, issues of cross-domain integration play a more prominent role and are increasingly effectively addressed by the research policy mix. Examples include policy initiatives such as the Excellence Initiative, the High-Tech strategy, the new Cluster of Excellence initiative and the Pact for Research and Innovation, all of which systematically link increased resource mobilisation to improvements in the co-ordination of knowledge demand, knowledge production and knowledge circulation. This is partly underpinned by new governance mechanisms like the Research Union Economy – Science which is intended to contribute to the monitoring of the High-Tech Strategy. An indicator of a cross-domain perspective is also the frequency with which cluster approaches are part of the policy measures, now finding its visible expression in the Clusters of Excellence initiative launched end of 2007.

The increased importance of the context of the European Research Area is acknowledged by research policy makers, e.g. in the High-Tech Strategy, and German actors are since long actively involved in shaping the ERA, e.g. as core providers and participants of pan-European research infrastructures of frequent participant of all types of FP projects. However, this increased importance is only partly reflected both in public debates as well as in the new internationalisation strategy. The European dimension and related opportunities are still rather superficially covered but the development of a European strategy is announced. A closer look at the four main domains analysed in this report reveals that the role of the European Research Area for the dynamics of the German research system and policies, although increasing, remains still limited. The system size, which constitutes more than one quarter of the EU research area, is an important explanatory factor.

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Chapter 1. Introduction

1.1 Scope and methodology of the report in the context of the European Research Area and the Lisbon Strategy

As highlighted by the Lisbon Strategy, knowledge accumulated through investment in R&D, innovation and education is a key driver of long-term growth. Research-related policies aimed at increasing investment in knowledge and strengthening the innovation capacity of the EU economy are at the heart of the Lisbon Strategy. The strategy reflects this in guideline No. 7 of the Integrated Guidelines for Growth and Jobs. This aims to increase and improve investment in research and development (R&D), with a particular focus on the private sector. One task within ERAWATCH is to produce analytical country reports to support the mutual learning process and the monitoring of Member States' efforts.

The main objective is to analyse the performance of national research systems and related policies in a comparable manner. The desired result is an evidence-based and horizontally comparable assessment of strength and weaknesses and policy-related opportunities and risks. A particular consideration in the analysis is given to elements of Europeanisation in the governance of national research systems in the framework of the European Research Area (ERA), relaunched with the ERA Green Paper of the Commission in April 2007.

To ensure comparability across countries, a dual level analytical framework has been developed. On the *first level*, the analysis focuses on key processes relevant to system performance in four policy-relevant domains of the research system:

1. Resource mobilisation: the actors and institutions of the research system have to ensure and justify that adequate public and private financial and human resources are most appropriately mobilised for the operation of the system.
2. Knowledge demand: needs for knowledge have to be identified and governance mechanisms have to determine how these requirements can be met, setting priorities for the use of resources.
3. Knowledge production: the creation and development of scientific and technological knowledge is clearly the fundamental role of a research system.
4. Knowledge circulation: ensuring appropriate flows and distribution of knowledge between actors is vital for its further use in economy and society or as the basis for subsequent advances in knowledge production.

These four domains differ in terms of the scope they offer for governance and policy intervention. Governance issues are therefore treated not as a separate domain but as an integral part of each domain analysis.

On the *second* level, the analysis within each domain is guided by a set of generic "challenges" common to all research systems that reflect conceptions of possible bottlenecks, system failures and market failures (see figure 1). The way in which a specific research system responds to these generic challenges is an important guide for government action. The analytical focus on processes instead of structures is conducive to a dynamic perspective, helps to deal with the considerable institutional diversity observed, and eases the transition from analysis to assessment. Actors, institutions and the interplay between them enter the analysis in terms of how they contribute to system performance in the four domains.

Figure 1: Domains and generic challenges of research systems

Resource mobilisation	Knowledge demand	Knowledge production	Knowledge circulation
• Justifying resource provision • Long term research investment • Barriers to private R&D funding • Qualified human resources	• Identification of knowledge demand drivers • Co-ordination of knowledge demands • Monitoring of demand fulfilment	• Quality and excellence of knowledge production • Exploitability of knowledge production	• Knowledge circulation between university, PRO and business sectors • International knowledge access • Absorptive capacity

Based on this framework, analysis in each domain proceeds in the following five steps. The first step is to analyse the current situation of the research system with regard to the challenges. The second step in the analysis aims at an evidence-based assessment of the strengths and weaknesses with regard to the challenges. The third step is to analyse recent changes in policy and governance in perspective of the results of the strengths and weaknesses part of the analysis. The fourth step focuses on an evidence-based assessment of policy-related risks and opportunities with respect to the strengths and weaknesses and in the light of Integrated Guideline 7; and finally the fifth step aims at a brief analysis of the role of the ERA dimension.

This report is based on a synthesis of information from the European Commission's ERAWATCH Research Inventory[1] and other important publicly available information sources. In order to enable a proper understanding of the research system, the approach taken is mainly qualitative. Quantitative information and indicators are used, where appropriate, to support the analysis.
After an introductory overview of the structure of the national research system and its governance, chapter 2 analyses resource mobilisation for R&D. Chapter 3 looks at knowledge demand. Chapter 4 focuses on knowledge production and chapter 5 deals with knowledge circulation. Each of these chapters contains five main subsections in correspondence with the five steps of the analysis. The report concludes in chapter 6 with an overall assessment of strengths and weaknesses of the research system and governance and policy dynamics, opportunities and risks across all four domains in the light of the Lisbon Strategy's goals.

1.2 Overview of the structure of the national research system and its governance

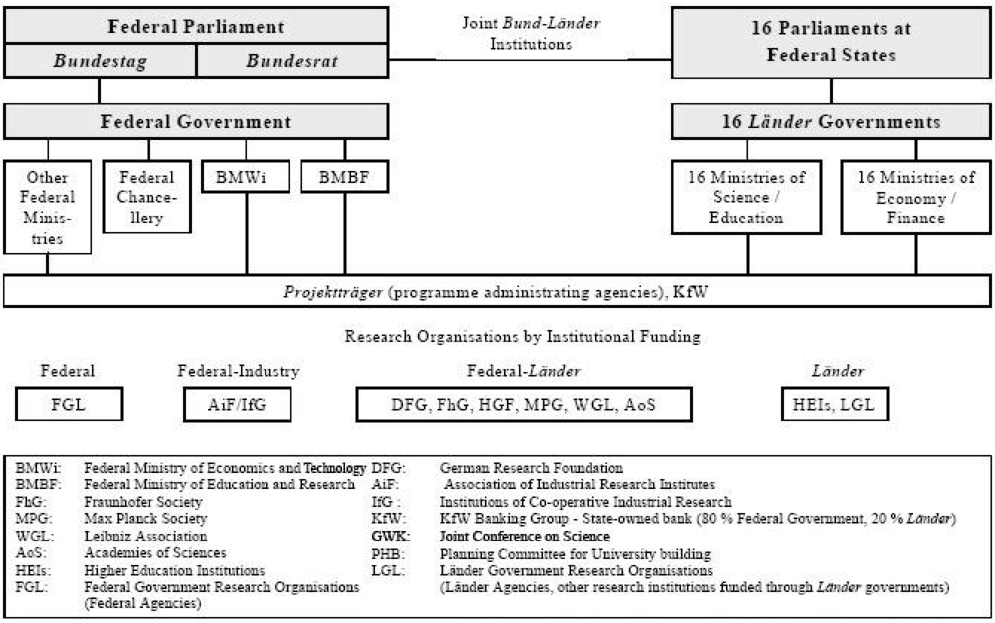
Measured in terms of R&D expenditure, Germany has the largest research system in the EU. It spends €58.848 billion per year (2006)[2] on R&D. It contributes significantly to EU resource mobilisation, being responsible for more than 27% of aggregate EU-27 R&D expenditure. R&D intensity (measured as a percentage of GDP) stood at 2.53% in 2006, which is significantly above the EU average of 1.84%. This share is

[1] ERAWATCH is a cooperative undertaking between DG Research and DG Joint Research Centre and is implemented by the IPTS. The ERAWATCH Research Inventory is accessible at http://cordis.europa.eu/erawatch/index.cfm?fuseaction=ri.home. Other sources are explicitly referenced.
[2] If not referenced otherwise, all quantitative indicators are based on Eurostat data.

fairly stable and is roughly similar to that of West Germany in the 1980s before German reunification. Due to the federal structure of the German political system, political responsibility for research policy and funding is shared between the Federal Government and the 16 state (Länder) governments (see figure 2 below). Most importantly, the states have the constitutional right to legislate on education, including universities, and they apply a range of programmes in research and in innovation policy. Apart from the funding for the considerable R&D expenditures of universities, however, most public resources for R&D come from the Federal level.

At the Federal level, the BMBF (Federal Ministry of Education and Research) has the main responsibility for research policy. The BMWi (Federal Ministry of Economics and Technology) is responsible for technology policy and some areas of R&D policy. Its current remit comprises not only SME-oriented indirect measures and energy research, but also aerospace and transport research, business R&D and patent issues. Each sectoral ministry has its own research institute(s). The German Parliament has a permanent Committee on Education, Research and Technology Assessment and has to approve the research budget. At the state level, responsibility is usually shared between the science and education ministry and the economics ministry. The main body for coordination of research policy between federal and state governments is the Joint Science Conference (GWK).

Figure 2: Overview of the governance structure of the German research system



Source: ERAWATCH Research Inventory, http://cordis.europa.eu/erawatch/index.cfm?fuseaction=ri.content&topicID=35&countryCode=DE&parentID=34

Unlike in other countries, there is no strategic policy council to coordinate research and/ or innovation policies. Some aspects of the work of a strategic council for research policy are performed by the German Science Council (Wissenschaftsrat), a joint institution with representatives from both federal and state levels, whose main function is to evaluate and advise on the development of higher education institutions, science and the research sector.

The Deutsche Forschungsgemeinschaft (German Research Foundation, DFG) is the central funding agency for basic research in Germany, complementing its institutional funding with project-type funding. Most publicly funded R&D programmes are administered and managed by implementation agencies (“Projekttraeger”), which are mostly located in large research centres. The central concern of the German Federation of Industrial Research Associations "Otto von Guericke" (AiF) is the promotion of applied R&D for the benefit of small and medium-sized enterprises.

Private R&D performers are responsible for 69.6% (2006) of the German R&D expenditures. Politically they are often represented by the "*Stifterverband für die deutsche Wissenschaft*" (an association of mainly private science-funding bodies).
The nearly 350 universities form the backbone of the German public research system, performing 16.5% (2006) of R&D if measured in expenditures. The German Rector's conference (HRK) is the umbrella organisation.
In addition, there are four important public non-university research organisations:

1. The MPG (Max Planck Society) currently maintains 80 institutes, research units, and working groups mainly in the field of basic research.
2. The FhG (Fraunhofer-Society) offers scientific and technical expertise on the market for research and development services, in particular for SME.
3. The HGF (Helmholtz Association) is Germany's largest scientific research community. It has been commissioned to perform research which contributes substantially to answering the major challenges facing science, society and industry.
4. The WGL (Leibniz Society) is working at the interface of problem-oriented basic research and applied research.

Another relevant block of public research performers consists of Government agencies and institutes performing research, which have organised themselves under the umbrella of "AG Ressortforschung". All public or publicly governed research organisations together perform 13.9% (2006) of the total R&D.

Chapter 2. Resource mobilisation

The purpose of this chapter is to analyse and assess how challenges affecting the provision of inputs for research activities are addressed by the national research system: its actors have to ensure and justify that adequate financial and human resources are most appropriately mobilised for the operation of the system. A central issue in this domain is the long time horizon required until the effects of the mobilisation become visible. Increasing system performance in this domain is a focal point of the Lisbon Strategy, guided by the Barcelona objective of a R&D investment of 3% of GDP in the EU as a whole and an appropriate public/private split.
Four different challenges in the domain of resource mobilisation for research can be distinguished which need to be addressed appropriately by the research system and research policies:

- Justifying resource provision for research activities
- Securing long-term investment in research
- Dealing with uncertain returns and other barriers to private R&D investment
- Providing qualified human resources.

2.1 Analysis of system characteristics

2.1.1 Justifying resource provision for research activities

The need for Germany to position itself at the forefront of scientific and technological progress in order to preserve future prosperity and competitiveness has always been emphasised in policy documents as a justification for channelling resources into research. Examples include the agreement between the Christian Democratic and Social Democratic parties in 2005 to form a coalition government and the National Reform Programme. In recent years, globalisation is frequently used as a rationale to legitimise higher public funding of R&D (e.g. BMBF, 2006b). For nearly 10 years, the main analyses of the Federal Research Ministry have been presented in the "Report on the technological competitiveness of Germany". These reports and its successor, the "expertise on research, innovation and technological competitiveness", are produced annually and are always the subject of a parliamentary debate. Before 2005, the research-related aspects of the Lisbon Strategy, and in particular the Barcelona 3% objective, did not play a major legitimising role; however, under the current Government this has changed (see 2.3).

The enhancement of public understanding of science and humanities is another way to improve the justification of resource provision. One important instrument is the "Year of Science", an awareness raising campaign involving all big science organisations which focuses each year on a different topic. 2007 has been the "Year of the Humanities" and 2008 is the "Year of Mathematics". The financial support of BMBF to the activities is between €5m and €13m. Each of the Years of Science is evaluated independently ex post, although with mixed results (Schnabel, 2008).
The private sector, in particular through industry associations, has also run a number of awareness campaigns promoting S&T studies in schools and among the general public.

The importance attached to the role of research in maintaining competitiveness is only partially reflected in the share of the total government budget that is allocated to public R&D expenditure. At 1.67% (2006) and provisionally 1.73% (2007) it is still slightly above the EU 27 average of 1.62% (2006), but has declined by comparison with its level of over 2% in the early 1990s. The main explanation for this pattern lies in the competing demands for resources brought about by German reunification. More recently, rising unemployment and also increasing expenditures on interest and debt management were the main drivers of competing demands.

2.1.2 Securing long-term investment in research

Three main partners interact to secure the necessary long-term investment for research and research infrastructures. They are: the federal government, within which the Ministry of Research and Education is the key actor; the regional governments, which are responsible for university funding; and the private sector, which is responsible for private R&D investment. As institutional university research is financed at regional level, the 16 states (*Länder*) together provide more than half of all public R&D funding. Based on a formal agreement concluded in 1975, the federal and the state levels coordinate joint block funding of the non-university public research system via the GWK and the competitive funding of basic research through the German Research Foundation. The total amount of this joint block funding is about €5.1 billion

(2005, last year for which expenditure data is available). In the Pact for Research and Innovation, the Federal and the state Governments agreed in June 2005 to increase the institutionally funded budget of each of the four main public research organisations and the DFG 2006-2010 by 3% per year. This is complemented by project-based R&D funding which is mainly provided at federal level, and which reached solely in the 2008 BMBF budget €3 billion. Although BMBF, who mobilises around 58% of the federal financial R&D resources for 2008 (BMBF, 2008a), has primary responsibility for coordinating all of them, other ministries decide on their own R&D activities independently. Important public R&D resources are also provided by the BMWi (19%) and the Ministry of Defence (11%).
The financing commitments have to be implemented through the parliamentary budgeting processes at both state and federal level. At the federal level, there is five-year budget planning in a rather aggregate form, while the details are implemented in annual budgets adopted by the Parliament. However, multi-annual resource commitments are possible. In this complicated multi-level resource provision structure, in which long-term financial commitments always have to be negotiated, significant increases in public funding are not easy to achieve. For instance, it was only thanks to its majority in both chambers of the parliament that the government was able to implement the “Six billion Euro for R&D” programme (see section 2.3).

To secure long-term investments, many large research facilities are provided by research institutes that are organised as not for profit organisations and funded by the state (in particular, the Helmholtz centres). At the federal level, the focus is on facilities for physics. The funding decision for new facilities is usually based on recommendations of the Science Council. The use of the facilities made available by universities is enhanced by a specific project funding line. Federal funding for large facilities was €705 million in 2006 (BMBF, 2008a).

Germany takes an active part in all international organisations providing research infrastructures which are financed and operated jointly with partner states. With regard to the financial contribution, the most important organisations are the European Space Agency (ESA), for which Germany provides €573 million (2005) and the European Organization for Nuclear Research - European Laboratory for Particle Physics (CERN). Institutional funding for large international research facilities was nearly €200 million (2006) (BMBF, 2008a); this is supplemented by project funding. Germany is also a member of the ITER consortium for the fusion research reactor. Experts estimate that German companies/research organisations received about €900 million from the EU Framework Programme (FP6) in 2005. However, no official data are available. In addition, the new Länder receive funding through European Structural Funds which is partly also used for R&D funding (see e.g. ERAWATCH Network, 2007). However, some of the new Länder cannot rely to the same extent on this source for the period 2007-2013 as before, as some parts of Saxony, Saxony-Anhalt and Brandenburg are now phasing-out regions. Overall, the measured share of R&D expenditures financed from abroad - at 3.8% (2006), of which more than two thirds go to the private sector (Statistisches Bundesamt, 2008) - is relatively minor.

Institutionally, therefore, the basic mechanisms for securing long-term investment in research are well established, but making changes is complicated. For long-term investments in research, government funding plays the most important role. Measured as a percentage of GDP, publicly funded R&D expenditures - at 0.76% (2004) – are above the EU 27 average of 0.64% but are significantly below 1%. However, the share of public funding in total R&D funding dropped by more than 6% between 1993 and 2003 (ERAWATCH Network, 2006) and, in particular, expenditure by the *Länder* declined in relative terms and between 2002 and 2005 even in absolute terms. Enhancing the mobilisation of public resources is therefore regarded as an important challenge for the German research system (BMBF, 2006b, Rammer, 2007), which has been increasingly addressed at the federal level since 2006 (see section 2.3).

2.1.3 Dealing with uncertain returns and other barriers to private R&D investment

There are a range of actors and mechanisms in the German research system whose task is to successfully deal with barriers to private R&D investment. Two thirds of R&D is financed by the private sector. More than half of this is directed towards the "R" component, and mostly to applied research. 87.3% (2006) of private R&D is conducted in firms with more than 500 employees (Stifterverband, 2008). About three quarters of business R&D is conducted by large multinational firms who can more easily handle the risk of R&D investments (Belitz, 2006). Foreign affiliates play an important role in business R&D. However, as data from the German science statistics (Stifterverband, 2006) suggest, they finance their R&D expenditure mainly from resources earned in Germany. The five biggest German-owned R&D investors, which belong to the world top 25, are Volkswagen (4.92 billion in 2007) Daimler (€4.89 billion), Robert Bosch (€3.56 billion), Siemens (€3.37 billion) and BMW (€3.14 billion) – all except Siemens in the automobile sector (European Commission, 2008).

The conventional funding mechanism for business R&D is intramural and internal funding, favoured by a long-term orientation encouraged by cross-ownership of company shares by other firms and banks. However, this model has been declining in recent years. Historically, other capital market mechanisms, such as venture capital, have played a minor role and for the most part are still used only for the 'new' R&D-intensive sectors, such as biotechnology. Availability of venture capital was adversely affected by the capital market downturn after 2001 and is also constrained by general corporate tax legislation (EFI, 2008). One measure to address this is the "*High Tech Gründerfonds*" with a budget of €260 million over five years 2005 to 2009, which has recently been increased by private funds. It was one of the results of the "partner for innovation" initiative which was chaired by the former chancellor and brought together a range of eminent industrialists, politicians and scientists between 2004 and 2006. Private foundations have so far played only a marginal role in the support of business R&D. Many smaller private foundations are managed through the *Stifterverband für die deutsche Wissenschaft,* which channelled €96 million into research in 2005.

Direct federal government funding of business expenditures for R&D has been constantly decreasing in relative terms and now accounts for 4.5% (2006). In most sectors it is below 10%, and hence less important for mobilising business R&D resources. The sole exception – albeit a significant one - is Aerospace R&D, which receives about 55% of its funding from government. An increasing share of 40% (2006) of the 1.85 billion Euro public funding is provided by the Ministry of Defence (BMBF, 2008a). Other public support for industrial R&D mainly takes the form of grants for collaborative research in programmes of the Research Ministry (23%) and the Ministry of the Economy, here also including indirect R&D support for SME and

new firms (31%, with shrinking volume between 2003 and 2006). One important institutional arrangement is the joint funding with industry of collective industrial research under the umbrella of the German Federation of Industrial Research Associations "Otto von Guericke" (AiF), which is often underpinned by sector-specific R&D institutions. In some of the *new Länder*, European Structural Funds play an important role in support programmes and infrastructure for business R&D and innovation (ERAWATCH Network, 2007).
Other instruments, such as grants for industrial researchers and specific fiscal incentives for R&D on top of the customary treatment of R&D as a fully tax-deductible expense, were abandoned at the end of the 1980s as their effectiveness was judged to be limited, even though some of these instruments were still used in Eastern Germany in the first transition period.
Indirect public support through the facilitation of venture capital and the provision of guarantees and loans has a long tradition and is mainly managed by the "*Kreditanstalt für Wiederaufbau*" (KfW), which acts as the government's main capital provider for a range of customers, including companies performing R&D (Rammer, 2007).

The performance of the system with regard to private R&D is often viewed as strength of the German research system (e.g. BMBF, 2006b). In the last decade, funding of R&D by business has continued to increase at a rate roughly equal to the EU average (Grablowitz et al., 2007). Privately funded R&D expenditure accounts for 1.67% of GDP (2004), which is far above the EU 27 average of 1.00% (2005). Many German companies are among the top R&D resource providers in their respective sectors (European Commission, 2007). Also the main mode of government support to private R&D, grant-based competitive funding, is assessed as highly effective (BMBF 2007b), an assessment also confirmed by OECD (2006). Any challenges referred to with regard to business R&D (e.g. Rammer, 2007), in fact tend to be related to the structure of private R&D demand (see section 3.1.1).

2.1.4 Providing qualified human resources

Germany is characterised by a well established higher education system, which enjoys a strong reputation in many areas. The so-called "Humboldt model" of combining research and educational activities in universities remains important and has led to a broad research base. This has it made possible to endow large numbers of students with research-oriented qualifications.

However, the Humboldt model has also resulted in a rigid pattern of typical researcher careers, with a high degree of dependence on the supervising professor during the PhD and PostDoc stages, which are the most productive phases. This has increasingly been seen as a bottleneck and a disincentive, representing an obstacle to the recruitment of well qualified young researchers. In recent years worries about the risk of a brain drain of German researchers to other countries, in particular the US, have been voiced by a range of actors and have been taken up in the media. Policy measures aimed at improving the careers of young researchers have always been controversial. In 2002, the previous government introduced a reform in the career track of post-docs (*Juniorprofessur*) on a voluntary basis to allow earlier independent research and a more predictable career path. However, implementation so far by universities has fallen short of expectations, and career prospects after completion of the junior professorship are still uncertain. The maximum duration of a series of temporary contracts for researchers was limited to 12 years and restricted to

the qualification phase, although the time limit was made more flexible in 2007. This has created more uncertainty for a group of researchers who have not yet obtained a permanent contract through a professorship. In addition to these regulations, the widening range of Federal research programmes contains measures which are specifically focused on supporting promising groups of young researchers.
Improved qualification and support for junior researchers in public research organisations are also an element of the Pact for Research and Innovation. The first Government monitoring report 2007 concludes that visible improvements have been reached, with the exception of the role of women researchers (BLK, 2007).

In science and technology related areas, in particular, German universities have been able to attract foreign students and researchers, and exchange programmes are well established. Two federal institutions - the *Deutscher Akademischer Austauschdienst* (DAAD) and the Alexander von Humboldt Foundation - provide a number of support programmes. With the German immigration law finally being adopted in 2004, the legal status of foreign students and researchers became clearer and, even before that, specific measures had been put into place to encourage highly-skilled immigrants.

Assessments of the system's performance in terms of providing researchers are not unanimous and they tend to follow a cyclical pattern (Rammer, 2007). After these concerns reached a peak the end of the 1990s and decreased thereafter, more recent studies have again tended to emphasise the scarcity of suitably qualified people, and the lack of highly skilled young people in particular (when comparing internationally), as a weakness of or at least threat to the system (BMBF, 2006b, 2007a). The main reason has been a decline in the numbers of graduates in science and engineering between 1998 and 2002. The comparatively low percentage of women among science graduates is also mentioned as problem. However, more recent data indicates that since then a continuous increase can be observed, reaching a total of 95.180 (2006) which is 13.000 more than 1998. With the completed transition towards a bachelor and master system at German universities, the number of graduates in general is expected to show a further significant rise, at least temporarily, due to accelerated studies and lower drop-out rates.

2.2 Assessment of strengths and weaknesses

The domain of resource mobilisation for R&D is a strength of the German research system, fostered by stable institutional arrangements. However, a drawback is the complicated co-ordination of increases of public financial resources in the federal structure. The main strengths and weaknesses can be summarised as follows:

STRENGTHS:	WEAKNESSES:
- Stable mechanisms in place to ensure long-term research funding - Functioning mechanisms for the provision of a strong human resource base for R&D - The two-thirds share of private R&D funding already meets Lisbon objectives	- Necessary multi-level negotiations for increases in long-term public funding are time-consuming and require political majorities, which are often difficult to achieve

2.3 Analysis of recent policy changes

With regard to resource mobilisation objectives, the coalition government, comprising the Christian Democratic and the Social Democratic parties, has given high priority to achieve the target of R&D expenditure reaching 3% of GDP by 2010, emphasising this in the preamble to its coalition agreement of October 2005. It has confirmed this goal in the National Reform Programme, which was drafted immediately after the new government having taken office (Bundesregierung, 2005). The contribution of the states to achieve the goal was confirmed in a joint declaration of Federal level and the states (GWK, 2008). Latest available data is for 2006 and confirms an increase of public and private R&D expenditure and a slight increase of R&D intensity. This does however not account yet for a number of relevant recent policy changes which may change this picture.

Challenge	Main policy changes 2007/2008
Justifying resource provision for research activities	-
Securing long-term investment in research	Implementation of "Six Billion Euro Programme for R&D" in the 2008 Federal budget Agreement on Higher Education pact 2020
Dealing with barriers to private R&D investment	Implementation of "Six Billion Euro Programme for R&D" in the 2008 Federal budget Law on Venture Capital
Providing qualified human resources	Transposition of EU VISA directive into national law Funding of further 21 PhD graduate schools in the second round of the Initiative for Excellence

The "Six Billion Euro Programme for R&D" for the period 2006 to 2009 is being implemented in the government budgets for 2007 and 2008. It was approved by the Federal government in April 2006. Besides additional funds for the Initiative for Excellence, it provided the resource base for the implementation of the High-Tech Strategy adopted at the end of August 2006 (BMBF, 2006c, see section 3.3 for more details). Two thirds of the funds are for the BMBF, which is also the lead manager of the programme. €1.2 billion go to BMWi programmes, and the rest is divided between various other federal ministries. What can be indeed observed is that after a period of stagnation in real terms, federal public R&D funding has increased by nearly 25% between 2005 and 2008 (plan). One expected impact is the mobilisation of additional R&D investment from the *Länder* and business. To this end, parts of the additional budget are to be channelled into industry, in particular SMEs. This is in the form of increasing the budgets of existing collaborative programmes and a new grant-based type of support to public sector institutions that conduct research for SMEs (for details on the latter, see the country report for 2007, Grablowitz and Nill, 2008). While effects of the circulation of knowledge between sectors are to be expected, the effect in terms of total resource mobilisation remains to be seen.

Another measure which may leverage *private R&D* is the Law on the Modernisation of Framework Conditions for Private Equity. This has been passed by the German Bundestag end of June 2008. The core is a new Law on Venture Capital which improves tax regulations for investments into young technology companies. The new Expert Commission Research and Innovation, which is now responsible for delivering the reshaped yearly reports on technological competitiveness, assesses the (draft) law as being too restrictive to allow for substantial improvements (EFI, 2008).

With regard to policies on *human resource mobilisation* and long-term university research infrastructure provision, the funding trends at *Länder* level – where the political responsibility lies - seem to run counter to recent federal budget increases (Rammer, 2007). The powers of the states concerning universities have actually been strengthened as a consequence of the recent huge effort to reform German federalism. Nevertheless, given the growing number of students, an agreement between the federal and the regional level concerning the long-term funding of the higher education sector (Higher Education Pact 2020) has been concluded mid 2007 after tough negotiations to increase the number of place for students. Here, a new burden-sharing model for research and education at universities has emerged. It consists of compensation measures between regions for the costs of students, burden sharing for large infrastructure investments and additional federal funds for the overheads of DFG projects, to facilitate the transition to full-cost budgeting by universities.

Two other recent policy measures with regard to human resource mobilisation are worth brief mentioning:

- In the second round of the Initiative for Excellence (for details see section 4.3) decided in October 2007, the number of PhD graduate schools funded was increased from 18 to 39. Each school receives around €1 million per year.
- In March 2007 the European VISA directive for scientists was transposed into German law as amendment to the immigration law. Instead of a prior check by foreign authorities and the German Agency for Employment, now a research contract with a recognised institute can serve as basis for visa.

2.4 Assessment of policy opportunities and risks

The main opportunities and risks for resource mobilisation in Germany arising from recent policy responses and in the light of the Lisbon Strategy relate to financial resource mobilisation challenges. They can be summarised as follows:

POLICY OPPORTUNITIES:	POLICY-RELATED RISKS:
- Increased volume of federal resource mobilisation through the "Six billion Euro programme"	- Public resource mobilisation, in particular at the Länder level, is insufficient to meet the Lisbon target - Private resource mobilisation might not respond to increased incentives to the extent anticipated

It is worth noting that despite the increased funding volume, public resource mobilisation seems to fall short of the German 3% Lisbon target for 2010. Even if continued in a similar range 2010, the additional federal six billion Euro over four years cover less than one fifth of the 16 to 24 billion Euro which are estimated as being necessary 2010 in comparison to 2005 (GWK, 2008). Experts have estimated that an additional public investment of six billion each year would be needed to achieve the public 1% part of the Lisbon objective (BMBF, 2006b). Additional private R&D funding between 2005 and 2008 is estimated at 7 billion Euros, albeit with decreasing growth rates (Stifterverband, 2008). Given the barriers to private R&D, it remains to see if the public funding increase intended to leverage private R&D will lead to further increases. If remaining resources were to come from the *Länder*, their expenditure trend until 2005 would need to be reversed.

2.5 Summary of the role of the ERA dimension

Overall, the role of the European Research Area for financial resource mobilisation for research in Germany remains limited. The Lisbon strategy was instrumental for the Government to prioritise the 3% target and to increase funding at federal level. Germany funds and participates actively in all important pan-European infrastructures. The share of the EU Framework Programme is with less than 2% of total German R&D funding rather limited, and the share of 20% of total competitive FP funding which flows to Germany roughly equals the country's share in the provision of the general EU budget (BMBF, 2008b).
With regard to human resources, Germany participates actively in European mobility initiatives and was one of the first countries which transposed the VISA directive into national law in form of an amendment to the immigration law.

Chapter 3. Knowledge demand

The purpose of this chapter is to analyse and assess how knowledge demand contributes to the national research system's performance. It is concerned with the mechanisms used to determine the most appropriate use of, and targets for, resource inputs. Main challenges in this domain relate to governance problems stemming from specific features of knowledge and the need for priority setting. These include:

- Identifying the drivers of knowledge demand
- Co-ordinating and channelling knowledge demands
- Monitoring and evaluating demand fulfilment

Responses to these challenges are of key importance for the more effective and efficient public expenditure on R&D aimed at in the Lisbon Strategy Integrated Guideline 7.

3.1 Analysis of system characteristics

3.1.1 Identifying the drivers of knowledge demand

Structure of knowledge demand

Direct private R&D demand is behind two thirds of R&D funding. The high demand for R&D in comparison with other countries is to a significant extent determined by the sectoral structure of the German economy. The latter reflects the economic importance of technology-driven competitive advantage based on the prominent role of early science-based industries such as chemicals, machine tools, electrical equipment and cars. It is hence driven by medium-high-tech manufacturing sectors. The latter perform 73.6% (2006) of manufacturing BERD, a share which is far higher than the EU average. Also much of the recent growth is concentrated in the well established sector of motor vehicles, as well as in chemicals. The increasing orientation of private R&D demand towards the automotive sector is perceived as a weakness in the light of the expected growth in demand in other areas of the world and possible future relocations of production (BMBF, 2006b).
Correspondingly, at 19.5%, the share of high-tech manufacturing in manufacturing BERD is much lower than the EU average, and even decreasing over the last years.

This is also reflected in BERD specialisation compared with EU 15, which shows a high (and rising) level of specialisation in motor vehicles, chemicals and fabricated metals (ERAWATCH Network, 2006). The share of BERD performed in the service sectors - which was 9.4% in 2006 - is growing but still among the lowest in the EU. This may be due in part to limited outsourcing from the manufacturing sector.
A further risk related to demand structure dynamics is seen in R&D-intensive sectors, where the number of firms is shrinking; and in certain fields such as ICT, electronics and media, imports of R&D-intensive inputs are rising (BMBF, 2006b).

With regard to R&D demand channelled through public R&D funding, more than half of the government budget appropriations (GBAORD) is non-targeted and often determined intrinsically by scientific actors (in particular general university funds, but also most of DFG funding), while 43.4% (2007) is directed towards specific socio-economic objectives. Specialisation of government-funded R&D compared to the EU 15 is more than 20% greater on social issues and the environment, and is more than 20% lower in human health, defence and agriculture (ERAWATCH Network, 2006).

However, as a result of the business culture and the stable sectoral structure in Germany, e.g. with the automobile sector even accounting for an increasing share in private knowledge demand, it is hard to find users for new knowledge that goes beyond incremental improvements. Also consumers tend to value solidity over novelty and belong in European comparative surveys to the innovation sceptics (European Commission, 2005). One result is that Germany rarely takes on a conventional lead market role for radical innovations derived from scientific breakthroughs in new fields of knowledge.

Processes for identifying the drivers of knowledge demand

There is an established set of mechanisms for identifying knowledge demand drivers. The conventional policy mechanisms were technology oriented. Technology forecasting, in the form of Delphi studies, has played a supporting role, particularly in the second half of the 1990s. The forecasting process "Futur" - The German Research Dialogue", which was operated between 2001 and 2005, was an attempt to bring about a more inclusive agenda-setting process (see also IPTS, 2006). Despite a positive evaluation by an international expert commission (Cuhls and Georghiou, 2004), the effects of Futur are unclear and the results have not been directly implemented in national R&D policy. A new foresight process has been launched end of 2007 (see section 3.3).
In addition, the German Parliament runs the "Office of Technology Assessment" (TAB), an advisory body attached to the Bundestag. It commissions studies to assess the impact of various technological developments and problems in the field of technology.
In recent years, both the Ministry, via its analyses on innovation and technology, and Parliament, via TAB, have taken greater account of the demand side.
Strategy papers or plans as tools to identify and articulate demand for knowledge, based on corresponding analyses, play a less prominent role than in other countries. In this respect, the High-Tech Strategy is somewhat of an exception (see section 3.3 for details).

The DFG is the main institution articulating new demands for basic research. One recent example was the request in October 2006 for changes in the stem cell law. While it is true that ethical limits play an important role in shaping societal demands in fields such as biotechnology (stem cell law, resistance to the application of green biotechnology) and nuclear technology (nuclear power phase-out), this argument cannot be generalised and it has not necessarily led to significant decreases in R&D in those fields.

The increased internationalisation of R&D is raising the importance of external drivers of knowledge demand. German multinationals, as well as many medium-sized enterprises, are outward-looking, and studies show that Germany is a very attractive location for private R&D activities in Europe (e.g. Belitz, 2006). At government level, however, there are hardly any measures in place to seek out potential external demand. The main mechanisms for demand articulation in the policy process remain inward looking.

Business R&D decisions are taken predominantly by firms based in Germany. Those R&D demands which are not met by in-house R&D capacities are directly articulated by funding R&D in the higher education and government sector, which receives 3-4% of total business R&D funding. Indirectly, and more importantly, demand is articulated through intermediaries and participation in the political process. One important intermediary in this respect is the *Stifterverband für die deutsche Wissenschaft*, which participates in political debates, manages its own small support programmes with funding of around €20 million a year and co-operates institutionally with the German Research Foundation and the Max-Planck-Society to help articulate business R&D demands into science. One example is the temporary funding of new university chairs *(Stiftungsprofessuren*).

3.1.2 Co-ordinating and channelling knowledge demands

Policy acts as a conduit for society's demands through the launching of research programmes and through its involvement in steering non-university public research institutions or, even more directly, by running designated governmental research institutes. German research and technology policies have preserved a mission-oriented element in the way they set priorities with regard to identified knowledge demands. Thematically oriented public R&D funding, as the main instrument, is dealt with at the federal level. The BMBF plays the main role. The basic approach, as expressed in dedicated research programmes, is technology-oriented. Areas on which attention is focused include ICT, life sciences, microsystems, nanotechnology, optical technologies, materials and production technologies, energy and sustainable development. Other ministries also have sectoral research programmes and institutes. These include the ministry of the economy and technology, the ministry of the environment, the ministry of defence, the ministry of transport, building and urban affairs and the ministry of food, agriculture and consumer protection. Taken together, about a quarter of government appropriations are primarily directed towards economic objectives (energy, agriculture, industry, space), while around 15% also include a social or environmental focus (land-use, environment, health). The channelling of demand over time has remained fairly stable, the exception being a significant decrease in the share of defence-related funding over the last ten years, down to 6.1% in 2007.

Coordination of the various targeted R&D activities in the different ministries is limited (see also Edler and Kuhlmann, 2008). There are formal procedures in place under the overall responsibility of BMBF, but their effectiveness beyond simple information exchange appears to be limited. There is no direct co-ordination of priority setting between the Federal and regional levels, although the regional level often tries to complement the federal initiatives (ERAWATCH Network, 2007). With the High-Tech Strategy of 2006, for the first time a more integrative approach has been chosen at the federal level (for details see section 3.3). Institutional R&D funding is largely decoupled from political priority setting. The only exception is the HGF, where funding has been reorganised along the lines of broadly defined thematic programmes. In some areas, such as defence and, to some extent, health, public procurement is used as an instrument to channel the demand for new knowledge.

Priority setting in general is mainly an administrative process organised by the ministry, based on consultation of experts, with economic actors being included in the process to varying degrees. The channelling of private demand signals is well established in classical areas of national R&D priority setting, mainly technology and/or sector-based topics such as production technologies, optical technologies and so on. Collaborative research in thematic research programmes seems to work as an effective tool in cases where the scientific and economic drivers of knowledge demand coincide, as in the case of life sciences or nanotechnologies. Here, the responsiveness of policy actors to demand from the private sector is very high. The same holds for other instruments aimed at encouraging private R&D. For example, the "Research Grant" to encourage more applied research by public R&D institutions (see section 5.3) has been proposed by the Federation of German Industries and channelled via the "partner for innovation" initiative mentioned in section 2.1.3.

Project-based funding within research programmes, as the dominant method of implementing public R&D priorities, allows a degree of flexibility and the inclusion of new focal points. Some of the increase in nanotechnology funding initially took place within existing schemes. The definition and approval of new research programmes is a time-consuming process and does not occur often. Changes, such as an increased articulation of demand for R&D with relevance for environmental protection or the rise of nanotechnologies on the research policy agenda, take place relatively slowly.

The international dimension, for example the EU with its Framework Programme, increasingly acts as an additional mechanism to channel the demand for knowledge. Until now, European activities have had only a minor direct effect on national priority setting. Care is taken to ensure that national priorities are sufficiently reflected in European programmes (BMBF, 2006a), and FP and national main thematic areas do generally coincide. German actors are also present in many ERANETS with a view to co-operation between national research programmes. However, the indirect impact of European priorities on research actors should not be underestimated. One indication is that, by 2005, FP 6 funding for German universities had reached more than 40% of the amount obtained by national direct project funding 2002-2004 (DFG, 2006).
Beyond the EU level, the bilateral relationships in Europe between Germany and France have always received particular attention. Joint intergovernmental research infrastructures such as the ISL and ILL are an example. There are regular meetings and efforts to co-operate on European research policy, as well as to increase bilateral co-operation between similar institutions in selected fields. The main themes addressed in the joint paper by the two governments in March 2006 are transport, ge-

nomics, nanotechnologies, cancer research and environmental sustainability (Auswärtiges Amt and Ministère des Affaires étrangères, 2006).

3.1.3 Monitoring and evaluating demand fulfilment

Since the mid-1990s, evaluation has become a core feature of the monitoring of new R&D policy initiatives (for details, see also Kuhlmann, 2003). As a rule, every new research programme is evaluated ex post by independent research institutes on behalf of research policy administrators, although the results are not always published. The main focus has been on impact analysis, but with the rise of co-operation and networking programmes process- and actor-oriented evaluations have also gained some ground. Competitive project-based funding plays an important role in the channelling of knowledge demand, and here every project is evaluated ex ante. Germany has significantly stepped up the use and methodological accuracy of evaluation throughout the life cycle of R&D policy measures. It is not always clear, however, to what extent the results of the evaluations have been considered before new R&D policy measures or programmes are launched. A positive example in this regard is the strategic evaluation of the "joint industrial research" mechanisms (Rammer, 2007).

In addition, since 1999 "system evaluations" of the German Research Foundation (DFG), the Max Planck Society (MPG), the Fraunhofer Society (FhG), the institutions of the "Science Community GW Leibniz (WGL)" and the national science centres in the "Helmholtz Society" (HGF) have been completed; this process was organised by the Science Council and frequently supported by international commissions (e.g. Wissenschaftsrat, 2001, for an overview, see Kuhlmann, 2003). The most recent one completes the evaluation cycle by evaluating the government research institutions of the federal sectoral ministries ("Ressortforschung") with respect to the relevance and quality of their R&D activities. The results on the main 13 institutions were published in April 2007, an evaluation of the further 39 institutions will follow by 2009. The work of the majority of these agencies is assessed by the German Science Council as being of high scientific quality, in particular in the field of applied research, concentrating on process development and method testing in the natural sciences, engineering, and social sciences. Some institutions, however, fall short in terms of both meeting the expectations of public administrators, and satisfying the quality standards of scientific communities (Wissenschaftsrat, 2007, see also section 3.3).
The results of such system evaluations have usually been widely discussed and have resulted in adjustments. For example, the large-scale research centres of the Helmholtz Association (HGF) have been found not to adequately fit the needs of the German R&D system, as they have performed R&D without a clear strategic focus (Wissenschaftsrat, 2001). Thus, their governance has been changed from centre-based funding into funding via thematic programmes, which also include joint R&D projects with business. The HGF programmes themselves are evaluated on a regular basis.
Relevant non-government actors which contribute to monitoring and evaluation are the German Research Foundation, and the *Stifterverband* and the *Centrum fuer Hochschulentwicklung* (for further details see section 4.1.1 and 4.1.2).

German practice in the area of evaluating the performance of research and research institutions has been assessed as strong. Little effort has been made, however, to coordinate and systematise evaluation practices (Kuhlmann, 2003).

3.2 Assessment of strengths and weaknesses

The main strengths and weaknesses of the German research system in terms of knowledge demand relate mainly to the way the channelling and co-ordination challenge is addressed. They can be summarised as follows:

STRENGTHS:	WEAKNESSES:
- Demand signals from classical industries well addressed by policies - Strong R&D programme basis enables responses to changes in demand - Well established evaluation mechanisms	- Demand signals outside the classical technologies/sectors or international demand signals not well addressed

3.3 Analysis of recent policy changes

The most notable recent policy initiative with implications for R&D demand articulation is the federal government's High-Tech Strategy, launched in August 2006 (BMBF, 2006c), of which implementation is ongoing. The strategy combines continuity with its focus on 17 targeted and "innovation fields" with some new elements in the strategic approach to public R&D demand articulation including also an integration of lead-market considerations and improvements of framework conditions (for a detailed analysis see the ERAWATCH country report for 2007, Grablowitz and Nill, 2008). Examples of thematic measures implemented in line with this new framework are the action plan "iD 2010" and the ICT 2020 research programme in the innovation field information and communication technologies, the NanoInitiative 2010, the first security research programme, the high-tech strategy for climate protection and a number of thematic public-private strategic alliances, e.g. in the domains of organic photovoltaics, OLED, molecular imaging and earth observation.

The particular aim of the High-Tech strategy is to improve the coordination between R&D activities by the federal-level ministries involved in R&D policy making. In this regard, it represents real progress, although the implementation until now does not always live up to this objective. For example, the high-tech strategy for climate protection remains a BMBF initiative, and other co-ordinated strategies see delays. The Expert Commission Research and Innovation proposes in this respect a streamlining of the fragmented competencies in the field of energy technologies (EFI, 2008).

The implementation of the High-Tech Strategy is monitored since 2006 by the BMBF high level advisory group "*Forschungsunion Wirtschaft – Wissenschaft*" (Research Union Economy – Science). Each member acts as promoter of one of the activities of the strategy. In fact that means that e.g. industry sector participants are responsible for the corresponding innovation fields. This might reinforce the "strengthening the strengths" element of the High-Tech Strategy.

Challenge	**Main policy changes**
Identifying the drivers of knowledge demand	Launch of new BMBF foresight process
Co-ordination and channelling knowledge demands	Implementation of innovation strategies for 17 thematic fields
Monitoring demand fulfilment	Concept and guidelines for Government research

In addition, the BMBF has started a new foresight process in September 2007. The new process combines foresight and innovation and technology monitoring, two well established elements of the German system for identifying knowledge demand drivers. The new process analyses the developments expected in the long term in selected areas of technology and research and shall identify new priorities; it conducts international comparisons and involves research organizations and industrial research (see http://www.bmbf.de/en/12673.php). The process is run by the Fraunhofer Institutes ISI and IAO. After the mixed experience with the Futur process, it seems to be partly a step back to the traditional focus on technology foresight. The above-mentioned new Expert Commission Research and Innovation recommends cross-ministry foresight measures and a link between foresight and the systematic development of criteria for the selection of priority fields (EFI, 2008).

In December 2007 the BMBF published the new "Concept for modern departmental research" of the German Government. This concept takes up "ten guidelines for departmental research" which were published early 2007 (Die Bundesregierung 2007a,b). The concept substantiates those guidelines in the areas of management of research and development, quality assurance, scientific networking and coordination. The concept intends to respond to results of the abovementioned major evaluation of the departmental research institutions (Wissenschaftsrat, 2007). It remains to be seen which steps towards implementation of the concept will be taken.

3.4 Assessment of policy opportunities and risks

The main opportunities and risks for knowledge demand in Germany arising from recent policy responses and in the light of the Lisbon Strategy can be summarised as follows:

POLICY OPPORTUNITIES:	POLICY-RELATED RISKS:
- More effective knowledge demand through better coordination between federal actors and more holistic approaches via the High-Tech Strategy	- It remains to be seen to which extent the new foresight process successfully addresses demand signals outside the classical technologies/sectors

The main policy opportunity in the domain is linked to the ongoing implementation of the High-Tech strategy. It is too early to assess to which extent this policy opportunity to further strengthen the existing strengths in demand channelling and overcoming co-ordination problems materialises in implementation practice. It is also too early to fully appraise the new BMBF foresight process, given that no results are available yet. However, while it seems to address the international dimension of knowledge demand drivers, its coverage beyond technologies and its links with priority setting demand remain uncertain.

3.5 Summary of the role of the ERA dimension

Until now, EU activities have had only a minor direct effect on national research priority setting. Care is taken to ensure that national priorities are sufficiently reflected in European programmes, and FP and national main thematic areas do generally coincide. EFI (2008) sees scope for improvement in the co-ordination of the High-Tech Strategy with the EU level. German actors are also present in practically all ERANETS. However, the indirect impact of European priorities on research actors should not be underestimated. Beyond the EU level, there are intensive bilateral relationships between Germany and France which also cover the R&D domain. Attempts of joint programming beyond a matching of related project activities are however limited.

Chapter 4. Knowledge production

The purpose of this chapter is to analyse and assess how the research system fulfils its fundamental role of creating and developing excellent and useful scientific and technological knowledge. Any response to knowledge demand has to balance two main challenges:

- On the one hand, ensuring knowledge quality and excellence is the basis of scientific and technological advances. It requires considerable prior knowledge accumulation and specialisation as well as openness to new scientific opportunities, which often emerge at the frontiers of scientific disciplines. Due to the expertise required, quality assurance processes are here mainly the responsibility of scientific actors, but may be subject to corresponding institutional rigidities.
- On the other hand, there is considerable interest in producing new knowledge which is useful for economic and other problem solving purposes. Spillovers which are non-appropriable by economic producers as well as the lack of possibilities and incentives for scientific actors to link to societal demands lead to an exploitability challenge.

Both challenges are addressed in the research-related Lisbon Strategy Integrated Guideline.

4.1 Analysis of system characteristics

4.1.1 Improving quality and excellence of knowledge production

The German capacity for the production of scientific knowledge is grounded in a well established university system and a large and unique non-university research system, based on four pillars with different missions. These are the MPG, HGF, WGL and FhG (see section 1.2). The highly differentiated structure of the German research system and its patterns of knowledge creation have proven to be highly durable over the long term (Grupp, 2004).
Scientific research in Germany has a clear focus on the natural sciences and engineering, which account for about half of the research activities in universities and three quarters of those in public research organisations. According to publication data for 2003, the largest proportion of publications is in clinical medicine, accounting for nearly a quarter of the publications in Germany. This field is followed by physics and chemistry, both with shares well above 10% (ERAWATCH Network, 2006). Engineering, coming fifth after biology/biochemistry, accounts for only about 5% of publications, but this small share is mainly due to the inward-looking orientation of German engineering, which leads to under-representation in the international SCI database, and the lesser relevance of scientific publications in this field (Schmoch, 2006). When measured in terms of citations, the patterns are similar, only biology/biochemistry and molecular biology have increased their shares, while the share of engineering has decreased. In relation to the EU 15, Germany shows a clear scientific specialisation in physics, material sciences and, albeit to a decreasing extent, chemistry (ERAWATCH Network, 2006).

The emergence of centres of excellence in basic research has traditionally been left to the research actors themselves, supported by funding from the DFG. This is beginning to change with the recent start-up of the "Initiative for Excellence", which targets top universities (see section 4.3). With regard to political support for targeted research, competence centres and competence networks in designated thematic areas and/or regions have already been growing in importance since the end of the 1990s. Starting with major initiatives in biotechnology, the sector-based competence centre and network approach has been widened by the BMBF into other areas such as nanotechnology, optical technologies and medical technologies. These initiatives have often taken the form of contests and have led to the re-structuring of thematic co-operation and co-ordination in a bottom-up way, whereas specific financial input has been comparatively marginal. The latter has changed with the new Clusters of Excellence initiative (see section 4.3).

Quality and excellence in academic research are fostered by a publicly funded independent institution, the German Research Foundation (DFG). The DFG grants more than €400 million per year for non-oriented basic research on a competitive basis according to scientific excellence and quality criteria based on peer review. In addition, the DFG uses a number of instruments to strengthen the scientific quality of the university system. These range from graduate schools and innovation colleges to awards for outstanding research achievements. In 2005, the DFG set up a specific institute for evaluation and quality assurance *(Institut für Forschungsinformation und Qualitätssicherung)*. Another institution which monitors the quality and excellence of the public research system is the German Science Council, with its regular evaluations and recommendations (see section 3.1.3 and below). Rankings of the research quality of universities as an additional quality control mechanism are a fairly recent phenomenon which has been particularly fostered by a private not-for-profit organisation, the Centre for Higher Education Development (Centrum fuer Hochschulentwicklung, CHE) of the Bertelsmann foundation and the foundation of the university rectors' conference (see, for example, Berghoff et al., 2006). However, every three years the DFG also publishes a university ranking based on the support received (e.g. DFG, 2006).
Beyond this, each pillar of the public research system has developed its own quality criteria. The MPG uses scientific excellence as its main criterion and the FhG uses contracts from the private sector. For the HGF and WGL, a number of additional criteria can be mentioned, such as the provision of a large state-of-the-art research infrastructure (for the HGF) or the contribution to evidence-based policymaking (for some WGL institutes). In recent years, the focus on research excellence has been given greater prominence in research policy (e.g. BMBF, 2006a).

The German research system has a good reputation for producing knowledge and the capacity to adapt to progress within established scientific fields or to combine them to create new knowledge. The openness to new opportunities is seen to be more problematic when these arise at the fringes of existing fields. There is a long tradition of programme-based government support for research in new high-tech fields. The stimulation and establishment of long-term multi-disciplinary and interdisciplinary research as a way of ensuring the openness of the knowledge production system to new opportunities has been a key objective in most competitive R&D programmes launched by the BMBF and other ministries. However, the strict separation of scientific disciplines in universities, as well as in the non-university research system, has prevented this objective from being achieved on a large scale. On the contrary, the recent focus on scientific publications as a core quality criterion for all elements of the public research system, e.g. in the evaluations of the Science Council, has further reinforced discipline-based research strategies, as it is much easier to situate publications within the context of existing disciplines.

The German research system has demonstrated a strong capacity for producing scientific and, particularly, technological knowledge. This is indicated by data on publications and patents (on the latter, see chapter 4.1.2), as well as a range of system evaluations conducted during the last decade. As visible in the ERAWATCH Research Inventory, Germany's knowledge output measured in publications per million inhabitants is 2005 lower than in many of the other leading European countries, and the average growth rate between 2000 and 2006 belongs to the lowest among EU countries. If measured in citations instead of publications, however, Germany still belongs to the leading group of countries with performances close to those of the US and the UK (Schmoch, 2006, see also ERAWATCH Research Inventory 2008).

System evaluations of the main research institutions (see section 3.3) confirmed a generally sound and appropriate division of labour, but an inadequate culture of exchange and cooperation and insufficient strategic planning and programming. Following the findings of the evaluations, some changes in governance and priority setting have resulted. However, a main target of criticism, the so-called *'Versäulung'* - the lack of cooperation between the different elements of the public research system and its negative impact on the openness towards new opportunities – persists (see e.g. Heinze and Kuhlmann, 2007). One further response has been the Pact for Research and Innovation agreed in June 2005. In exchange for the government's commitment to increases in funding, public research organisations have made commitments to increase the quality and performance of their R&D activities, by e.g. benchmarking strengths and weaknesses with regard to excellence, and by exploring new research fields including risky and non-conventional research.

4.1.2 Improving exploitability of knowledge

Ensuring exploitability of knowledge for economic and other societal uses has always been an important feature of the German research system. Patent law and other intellectual property rights institutions have been well established for a long time. Also the large proportion of private R&D indicates that knowledge production is highly market-oriented.

The technical universities, which are internationally renowned (e.g. RWTH Aachen and TU Munich) and which collaborate extensively with business, play a key role in matching knowledge production with economic specialisation. The four main economic sectors - machinery, electronic equipment, chemicals and motor vehicles - are also the four most important fields of technological knowledge production, together accounting for half of all German EPO patent applications. Pharmaceuticals and office equipment follow some considerable way behind. Patent specialisation relative to EU 15 confirms a high level of specialisation in motor vehicles and, to a lesser extent, machinery. Other fields of specialisation are fabricated metals and electrical equipment (ERAWATCH Network, 2006). This specialisation in medium-high rather than in high-tech sectors also manifests itself in the specialisation of business R&D. In general, there is a rather good fit between BERD and value added specialisation. One notable exception is electrical engineering which has lost some of is relative importance in business R&D due to larger increases in automobile R&D and larger increases in these sectors in other EU countries.

Economic exploitability is used as the de facto quality criterion for a number of public R&D support measures, mainly the pre-competitive programmes of BMBF and BMWi. One element covers the design of programmes and projects, to involve the main future users, such as industry, both in the setting up and in the implementation of the programmes. The quality of the proposals for the project-funded research by the BMBF is evaluated ex ante by expert panels, which often include researchers and representatives from industry associations. In general, all publicly funded projects have to develop an implementation plan as a part of their project proposal, describing how the potential results of the projects will be exploited. The organisation responsible for project management evaluates the achievement of these plans five years after the project is completed. Another element is the presentation of the results in a user-friendly way. Specific monitoring processes are often put in place to disseminate the results of the projects during the life-cycle of a programme. In addition, the results of all federal pre-competitive R&D projects are centrally accessible via a database (TIB Hannover).
The increasing focus on thematic and regional clusters and networking approaches in German R&D policy can be seen as a way to further improve the exploitability of research. Since the end of the 1990s, a cluster-based approach has been chosen, for example by the BMBF, to foster knowledge-based development of the East German *Länder* under the umbrella of the "entrepreneurial regions" initiative. One example is the "centres for innovation competency" programme, which supports research centres that meet international standards and gear their basic research towards future high technology markets. The cluster approach has been reinforced with the High-Tech Strategy (see sections 4.3 for details).

While the responsiveness to the demands of economic sectors is often high, in cross-cutting, policy-related fields it tends to be more limited; this is because the public research system is defined along rigid disciplinary lines, which makes it hard to respond when there is no clear-cut sector and/or technology to which the research can be attributed. Examples are research on sustainability issues, public health or mobility (beyond cars). In such areas, specific research institutes - often rather small ones - have emerged to fill this gap.

The main incentive for academic researchers to link up with economic and policy demands (besides future career prospects in the private sector) is the acquisition of additional funding. A number of Länder have started to use additionally acquired funds as one criterion for the distribution of institutional funding of universities. Experience in the private sector is also a main criterion for becoming a professor at one of the universities of applied science. For other university careers, however, academic quality criteria often dominate. Therefore, the exploitability of knowledge for policy-making and other societal purposes is additionally ensured by setting up specific institutes for evidence-based policy support. The institutes of the WGL, in particular, play an important role in providing evidence and science-based support for policy making. However, the institutes of the HGF are also involved in this field (e.g. on nuclear radiation issues).

Both the indicators and the existing system assessments provide evidence of the high performance of the German system with regard to exploitability of knowledge. With 269 EPO patent applications per million inhabitants (2005), Germany's patent output has nearly doubled over the last ten years and is nearly three times the EU 27 average of 101. A particular strength of the German system is the production of knowledge for established economic sectors, and corresponding incremental innovations which are highly dependent on knowledge accumulation and integration (e.g. Huebner and Nill, 2001; the feature is also highlighted in several of the annual reports on the technological competitiveness of Germany). Moreover, the strategic system evaluation of the "joint industrial research" mechanisms of the BMWi (Blum et al., 2001) generally confirmed the good system response. It pointed to a number of areas for improvement with regard to programme overlaps and more direct targeting of underlying market failures; these improvements have subsequently been implemented in the redesign of the programmes (Rammer, 2007).

4.2 Assessment of strengths and weaknesses

The main strengths and weaknesses of the German research system in terms of knowledge production can be summarised as follows:

STRENGTHS:	WEAKNESSES:
- Mechanisms in place to enhance scientific excellence of public research through DFG and Science Council - Strong focus on research closely linked to the economy's strengths	- The rigidity of the public research system, which is strongly geared towards traditional scientific disciplines, makes it difficult to adapt to new cross-cutting opportunities

There are strong system responses to both challenges in the domain. They take the form of quite stable institutional arrangements, such as the role of the German Science Foundation and the German Science Council in enhancing quality and excellence of knowledge production. Remaining main weaknesses are related to the adaptation to and enhancement of changes and are hence partly a reflection of the strength of the established system responses.

4.3 Analysis of recent policy changes

Enhancing knowledge quality and exploitability has always been a goal of Federal research policy. In particular the goal of strengthening exploitability of knowledge through enhanced science-industry co-operation is strongly underlined in the National Reform programme (Bundesregierung, 2005) and the High-Tech Strategy (BMBF, 2006c), with greater emphasis on clusters as a relatively new element, and it is also reflected in the new "Research Union Economy – Science" (see section 3.3).

Challenge	Main policy changes
Improving quality and excellence of knowledge production	- Implementation of second round of the Initiative for Excellence - Concept and guidelines for government research (see section 3.3) - Principles for a new law on and first steps towards more freedom for public research organisations
Improving exploitability of knowledge	- Cluster of Excellence initiative - Implementation of innovation strategies for 17 thematic fields - Innovative SMEs initiative

The implementation of the “Initiative for Excellence” agreed in July 2005 by the Federal and state governments by the DFG and the Science Council has continued (for a detailed analysis of the initiative see the ERAWATCH country report for 2007,

Grablowitz and Nill, 2008). A second round of selection of proposals has been completed in October 2007. The main aim is to support cutting-edge research at universities to create "beacons of science" with international visibility. Future concepts of further six universities were selected: Aachen, FU Berlin, Freiburg, Goettingen, Heidelberg and Konstanz, which will receive on average €21 million per year. In addition, further 20 "clusters of excellence" have been selected with the aim of strengthening co-operation between universities and non-university research institutions through the competitive funding of outstanding centres in specific interdisciplinary fields of research. Each will receive around €6.5 million per year.
In July 2008 DFG and the Science Council have presented a joint position paper on the further development of the Initiative for Excellence beyond 2011. They assess the interim results positively and argue for a continuation along the existing lines with increased funding to ensure sustainability of the desired structuring effects.

The combination of excellence and exploitability of knowledge is also the aim of research-based cluster initiatives between science and industry which are collected into a cluster strategy as part of the German High-Tech Strategy (BMBF, 2006c). Thematic cluster approaches as a tool to implement the 17 thematic field strategies (see section 3.3) have been reinforced. Specific support mechanisms for SME participation in high-tech clusters are provided by the “Innovative SMEs” initiative which was launched by BMBF in September 2007. Traditional combined grants are for SMEs complemented with consulting, quicker procedures and simplified requirements on the financial situation. The initiative builds on similar initiatives in the biotech and nanotech areas (e.g. BioChancePLUS), and extends it to selected other areas with high start-up and application potential.

Furthermore, a new "Clusters of excellence" initiative was launched by the Federal Ministry of Education and Research in August 2007. The competition is open to all scientific and technological fields in order to single out Germany's top cutting-edge clusters for awards and contribution to funding. Three competition rounds are foreseen, in each of which up to five clusters are selected which receive in total up to €200m over five years. This shall enable these clusters to boost their profile, eliminate impediments to their strategic development and grow into internationally attractive centres. It is hoped that this will have a mobilising effect comparable to that of the Initiative for Excellence. The funding shall include €60bn by the BMBF, €40-50bn by the *Länder* and at least €60-90bn by industry (GWK, 2008). In August 2008 the first five clusters have been selected in a two step process out of 38 applications:

- Forum Organic Electronics in the region Rhine-Neckar
- Cool Silicon – Energy Efficiency Innovations from Silicon Saxony
- Solar valley Middle Germany
- Aerospace cluster region Hamburg
- Biotechnology cluster "cell and molecule based medicine in the region Rhine-Neckar" (see www.spitzencluster.de for more details)

The focus in the selection process of an independent committee led by the president of the new German Academy of Technology Sciences was on strengthening and better commercial utilisation of existing strengths, including substantial financial contributions by the private sector. Hence it is not a surprise that the first five winners are rather clearly linked to established innovation fields.

Strengthening clusters and co-operation with industry has also been the focus for improvement of knowledge production performance of public research organisations in 2007 within the Pact for Research and Innovation. The first monitoring report of the Government concludes that a number of measures have been developed which could counterbalance the "Versäulung" of the science system. However, in the area of societal and industrial exploitability further efforts are needed. It is also envisaged to develop an indicator-based monitoring system on co-operations (BLK, 2007).

End of July 2008 principles of a new "freedom of science law" targeted at public research organisations have been presented by BMBF. The aim is to move towards global budgets, to give more freedom to MPG, HLG and FhG in using the money in order to keep best scientists and increase efficiency and to reduce the necessary approval stages for co-operations. However, no agreement on a law has been reached yet; therefore a step-wise approach is chosen with the aim of implementing steps which are feasible without law already in the 2009 government budget and its implementation procedures. The success of this endeavour remains to be seen.

4.4 Assessment of policy opportunities and risks

Recent policy initiatives in Germany relevant for the domain of knowledge production are in tune with the recommendations of the Lisbon strategy integrated guidelines, such as modernising management of research institutions and universities, strengthening centres of excellence, more effective and efficient public expenditure (IGL 7), the promotion of new technological initiatives based on public–private partnerships (although with a national focus) and the creation and development of networks of regional or local clusters to develop new technologies (IGL 10). The main opportunities and risks for knowledge production can be summarised as follows:

POLICY OPPORTUNITIES:	POLICY-RELATED RISKS
- Improved excellence and increased international attractiveness of public research system enhanced by the Initiative for Excellence - Further strengthening of exploitability of knowledge by reinforced cluster approaches	-

Hence with regard to the Lisbon goals no clear policy-related risks can be detected. It remains to be seen if positive interim assessment of first results of the Pact for Research with regard to responses to the "Versäulung" stabilises so that also this rather soft implementation process would turn into a policy opportunity.

4.5 Summary of the role of the ERA dimension

German research actors are participating in all ERA initiatives. However, the success rate of German proposals in the Framework Programmes is with 24% only European average (BMBF, 2008b). This may also reflect that processes to ensure excellence and exploitability of knowledge production still follow mainly a national logic, which is not surprising given the size of the national research system. Nevertheless there are some signs of change with the Initiative for Excellence and the new cluster competition which both highlight the international dimension as benchmark.

Chapter 5. Knowledge circulation

The purpose of this chapter is to analyse and assess how the research system ensures appropriate knowledge flows and sharing between actors. This is vital for its further use in the economy and society or as the basis for subsequent advances in knowledge production. Knowledge circulation is expected to happen naturally to some extent, due to the mobility of knowledge holders, e.g. university graduates who go on to work in industry, and the comparatively low cost of reproducing knowledge once it is codified. However, there remain three challenges related to specific barriers to knowledge circulation which need to be addressed by the research system in this domain:

- Facilitating knowledge circulation between university, PRO and business sectors
- Profiting from access to international knowledge
- Enhancing the absorptive capacity of knowledge users

Significant elements of Integrated Guideline 7 relate to knowledge circulation. To address them effectively requires a good knowledge of the system's responses to these challenges.

5.1 Analysis of system characteristics

5.1.1 Facilitating inter-sectoral knowledge circulation

Given its technology-based economy, there is a long tradition of knowledge circulation between knowledge creators and knowledge users in Germany, and the process is supported by a range of institutional and programme-based measures. Cooperation between industry and the science system is highly institutionalised, with a range of intermediaries and two core institutions. From the applied research side, the Fraunhofer Society has a strong reputation for applied research in collaboration with industry. Of its annual research budget of over €1 billion, around €600 million comes from contracts with industry and from publicly financed collaborative research projects. One third is contributed institutionally by the German federal and *Länder* governments. From the industry side, the main institution in this field is the German Federation of Industrial Cooperative Research Associations "Otto von Guericke" (AiF), a non-profit association that aims to promote applied Research and Development (R&D) for the benefit of small and medium-sized enterprises (for details, see section 5.1.3 below).

Furthermore, the *Fachhochschulsystem* (according to the ERAWATCH Research Inventory, more than half of the German universities are what are called universities of applied sciences) is geared strongly towards knowledge circulation and education; thus, even if the research content has been improved over the last few years with the help of designated BMBF programmes, it remains somewhat limited. As most of the teaching staff of the *Fachhochschulen* have business experience and work on practical (often S&T) issues, they usually have close ties with regional industry and most graduates are able to find work locally.

Besides the institutional settings, nearly all R&D programmes managed by the BMBF and BMWi, as well as regional R&D programmes, include a strong focus on knowledge circulation between the public R&D system and the private sector, either as a

separate set of projects within the overall programme or as an intrinsic element of all the projects funded under one scheme. The increasing focus on networking and cluster programmes described in sections 4.1.2 and 4.3 should be also seen as a driver for improved knowledge circulation between knowledge creators and knowledge users in general. One of the main aims of the BMWi's more innovation-oriented funding programmes is to enhance science-industry relations. Examples are the ProInno initiative and the "Promotion of Innovative Networks (InnoNet)" Programme, which is used to support the development of research networks comprising both small and medium-sized enterprises and research institutions.
Increasing circulation of knowledge between sectors is also an important focus of the work and the programmes of the *Stifterverband* (see also section 5.3). For example, most industry associations that are active in research launch PhD or post-Doc grant programmes via the *Stifterverband* and are regularly informed about the progress of the researchers funded.

Another more recent change in incentives is the change in the universities' IPR regime in 2002 so as to give the universities greater control over the intellectual property their researchers produce; this is modelled on the approach pioneered in the *Bayh-Dole Act* in the United States. This scheme is accompanied by the creation of transfer offices (*Patentverwertungsagenturen*) in most of the regions. The final impact of these measures is as yet unclear – on the one hand, it improves the visibility of value creation in public research, but on the other hand it might put a brake on the willingness of the private sector to cooperate with universities, if the universities themselves are too focused on using the research results to generate additional income. The US example has shown that funding of university research by the private sector has decreased significantly since the adoption of the Bayh-Dole act. A group of experts under the "partner for innovation" initiative sees a clear need to improve the business models of the transfer offices (Hoefer and Wengel, 2005).

The strength of inter-sectoral circulation of knowledge between science and industry, which is also highlighted in assessments (e.g. BMBF, 2006b), is to a certain degree also reflected in commonly used indicators. At 14.1% (2005), the share of HERD financed by industry is more than double the EU 27 average of 6.3%. After changes in the statistical measurement method, the share of GOVERD financed by industry is now 9.9% (2005), which is also above the EU 27 average of 8.3%. The lower difference in shares is a reflection of the particular specialisation of the German non-university research system, where the Max Planck Society plays a strong role which has no parallel in other countries.
The remaining weaknesses stressed in the system assessments relate rather to insufficient circulation of knowledge between the four pillars of the non-university public research system (HGF, MPG, FhG, WGL) and universities. This kind of knowledge circulation is less organised and does not perform as well, mainly owing to the diversity of topics covered in each of the organisations and their different missions. Knowledge circulation between the university system and the non-university system has been made the focus of a range of measures aimed at bolstering knowledge circulation, such as the joint appointment of HGF institute directors and university professors, and exchanges of PhD students.

5.1.2 Benefiting from access to international knowledge

German firms tend more to be 'first followers' rather than 'first movers', which means that access to international knowledge is crucial. The country's export surpluses in medium-to-high tech products would suggest that this strategy is successful. The strong reputation of German universities and companies worldwide gives them ready access to international knowledge. About 25% of private sector R&D in Germany is carried out by foreign affiliates, which are often operating since long in the country and are therefore well integrated in the research and innovation system, and about 20% of R&D contracts from German companies go outside the country (Belitz, 2006). However, recently there is a growing perception of possible costs of international knowledge circulation, such as the outsourcing of R&D to lower-cost locations with a high potential of well-qualified researchers, and a growing tendency of talented researchers to move to other locations, especially the US (Rammer, 2007).

Moreover, Germany's participation in the EU Framework Programme reveals a well developed network of connections. More than 80% of all EU collaborative projects involve German partners and around 20% of all competitive funds go to Germany (BMBF, 2008b). Usually, however, there is no direct national co-funding of applications to the Framework Programme. An exception is the contribution to the preparation of large projects as co-ordinator.

Scientific collaboration with other countries has a long tradition in Germany. However, an explicit Government strategy to incorporate internationalisation has only been published early 2008 (BMBF, 2008b; see section 5.3 for details). Bilateral agreements on R&D cooperation are in place with more than 50 countries. International scientific cooperation is co-ordinated by the International Bureau of the BMBF and supported by a web-based signposting and information service since 2002 (www.kooperation-international.de/en) as well as an English language internet portal (www.research-in-germany.de), which provides foreign researchers and scientists with information about research opportunities in Germany.

A number of institutions are active in promoting and funding exchange programmes and/or grants for foreign researchers in Germany or for German researchers elsewhere. The most prominent institutions are the German Academic Exchange Service (DAAD), the Alexander von Humboldt Stiftung and the agency *Invent*. Also, the DFG runs a number of programmes aimed at strengthening international research cooperation. Instruments include funding the participation of German researchers in international conferences and a joint DFG/NIH programme for PostDocs, as well as bilateral cooperation agreements. Most of the non-university research pillars, such as the HGF, MPG, FhG and WGL, have offices outside Germany in order to stimulate international cooperation although there still remain problems related to their internationalisation (for details see Edler, 2007, BLK, 2007).

As Germany has a relatively big 'internal science market', there is a certain language barrier in fields such as the social sciences or law where language plays an important role in formalising scientific ideas. As a result, there are a number of journals in German which are not well connected to the outside world. The language barrier also limits the effectiveness of the degree of openness of a range of national research programmes, in which the funding of foreign participants via subcontracts is to a certain extent possible. The current transition from the university degree system towards a bachelor and master system will improve compatibility with key partner countries both within and outside the EU.

While assessments of the system stress the fact that, generally speaking, the German innovation system is internationally well-connected (BMBF, 2006b), the system evaluations of the public research institutions have revealed considerable room for improvement as regards the international dimension of research (e.g. Wissenschaftsrat, 2001).

5.1.3 Enhancing the absorptive capacity of knowledge users

In general, the absorptive capacity, especially among SMEs, appears to be well developed, in view of the economy's basis in traditional technology and the high proportion of all enterprises (over 70%) that are engaged in innovation activities. Also, there are nearly 30 000 SMEs conducting their own R&D on a permanent basis; this is a high total, although for some time the total has been stagnating or even shrinking (Rammer, 2007). An important role in enhancing SME participation in R&D is played by the German Federation of Industrial Cooperative Research Associations "Otto von Guericke" (AiF). It is organised by industry along sectoral lines covering over 100 industrial research associations, including approximately 50,000 SMEs, and about 700 associated research institutions. The AiF lays the foundations for sector-specific industrial cooperative research in the pre-competitive stage and is organised by the industry itself. Since 2000, cross-sectoral interdisciplinary research in new technologies for the benefit of SMEs has also been supported under the ZUTECH programme. The work of the AiF is jointly financed by industry and the Federal government, via the BMWi budget. In addition, many innovation support measures of the states aim at enhancing absorptive capacity of small and medium enterprises (for overviews see e.g. GWK, 2008, BMBF, 2008a).

Highly qualified scientists and engineers are often recruited by the private sector following joint projects. This is especially true of the *Fachhochschulen* (universities of applied sciences), where training in a private sector company for two six-month periods during studies is compulsory. The percentage of scientists and engineers in the total labour force - at 5.8% (2007) – is significantly higher than the EU average of 4.9%. In the CIS 4 survey 2004, only 4.6% of all innovative firms gave ‘lack of qualified personnel’ as an important hampering factor; this is less than half of the EU 27 average. Also trends in the number of S%T graduates improve (see section 2.1.4)

Rammer (2007) concludes in his assessment of the coherence of the policy mix that the specific problem of the decreasing share of SMEs performing R&D highlights the only major gap between the challenges and the instruments in place to respond to them in Germany. There are only a few measures that help non-R&D performing enterprises to take up R&D activities, and those that are in place, like the ProInno programme of the BMWi, reach only a limited number of firms and have a low quantitative effect. However, it is debatable whether simply focusing on supporting R&D activities in SMEs is a sufficiently targeted response, because sectoral differences are important. In new sectors, the actual challenge might be about supporting new, R&D-intensive firms, which is tackled to some degree, whereas in other established sectors involvement in capital investments plays a more central role, and alternative policy measures focusing on the upgrading of human resources, such as 'life-long learning' programmes, might be also important.

5.2 Assessment of strengths and weaknesses

The main strengths and weaknesses of the German research system in terms of knowledge circulation can be summarised as follows:

STRENGTHS:	WEAKNESSES:
- High profile of knowledge circulation measures - Internationally well-connected research actors reinforced by a number of measures and institutions to ensure knowledge access - Broad R&D base in the private sector ensuring good absorptive capacity	- Weak dynamics of absorptive capacity with regard to new private research performers and the availability of S&T graduates

The strong system responses to knowledge circulation challenges are to a significant extent based on stable institutional arrangements, such as the role of the Fraunhofer Society and the AIF in enhancing knowledge circulation to the economic sector. The remaining dynamics-related weakness reflects drawbacks of this stability.

5.3 Analysis of recent changes and policy initiatives

The National Reform Programme confirmed the importance attached to policy goals in the field of knowledge circulation, mentioning knowledge and technology transfer, the support of clusters and regional support for science-industry links as the first three innovation- and technology-related goals (Bundesregierung, 2005). The High-Tech Strategy paved the way for new measures in this area (for details see Grablowitz and Nill, 2008). An important recent example are the new and reinforced cluster initiatives which were already described (see section 4.3), which also aim at ensuring a better circulation of knowledge. The "Research Grant" (*Forschungsprämie)* for public research organisations to enhance knowledge transfer to small and medium enterprises implemented in early 2007 has been complemented in October 2007 by a "Research Grant Two" for private not-for-profit research institutions.

After a long preparation time, in February 2008 the "Strategy of the Federal Government for the internationalization of science and research" was finally adopted (BMBF, 2008b). The strategy addresses four main objectives:

- Improving international collaboration in research and ensuring that Germany becomes a leading research location
- Making use of innovative potential by ensuring that German firms increasingly collaborate with the internationally leading high-tech regions and research centres
- Further developing the scientific collaboration with developing countries in order to improve education and research in those countries
- Assuming global responsibility for addressing the problem of global change, securing the energy supply, reducing poverty and controlling pandemics and contributing to the long-term international research agenda in the relevant scientific and technological areas.

New measures proposed to address those issues include improving mobility of young researchers, improving co-ordination of national, regional and international research programmes in complementary areas, and the promotion of the definition of an aligned and coordinated research agenda in international organisations. The strategy shall be evaluated by independent experts every three to five years. Another characteristic is regional and thematic focusing of strategies and measures. The first example of this new approach has been the Republic of Korea in 2006 and 2007. The next country under focus from 2008 onwards is India. Two important topics of bilateral co-operation are nanosciences and environmental technologies.

The strategy recognises the changing international landscape and related challenges. It builds and attempts to capitalise on the strengths of the German research system. There is a markedly national and global focus, expressed already in the title "Strengthening of Germany's role in the global knowledge society", while the European dimension and related opportunities are rather superficially covered. A European strategy is mentioned as element which needs further development.

Since July 2008 there is a "Central Innovation Programme" for SMEs (ZIM) of the BMWi (for a detailed analysis of the rationale see Rammer, 2008). It is intended to be the core programme for open market-oriented technology support for firms of the *Mittelstand* (with up to 500 employees) and replaces existing SME programmes like InnoWatt and ProInno. It runs until end of 2013 and concentrates in the first step on co-operation between SME and research organisations and network projects between SME, while a support mechanism for single projects shall follow 2009. It remains to be seen to which extent this simpler funding tool can also attract new SME into research which is one of the intentions.

Challenge	**Main policy changes**
Facilitating circulation between different research sectors	- Research Grant Two for private not-for-profit research institutions - Cluster of Excellence initiative (see section 4.3) - working of Research Union Economy Science (see section 3.3)
Profiting from international knowledge	- Federal Government strategy for the internationalisation of science and research
Enhancing the absorptive capacity of knowledge users	- Central Innovation Programme for SMEs - Federal Qualification Initiative

Further it is worth mentioning with regard to the enhancement of absorptive capacity that since early 2008 there is a new framework of the federal Government for lifelong learning, the "Qualification Initiative Advancement through Education". One of its initiatives targets at attracting more women into science and engineering professions. However, competencies for lifelong learning are mainly with the Länder and the social partners which has limited effectiveness in this policy field up to now (INNO-Policy TrendChart, 2007), hence the initiative can only be fully appraised when the implementation steps are specified. A first step was a qualification summit between federal government and the states in October 2008.

5.4 Assessment of policy opportunities and risks

The main opportunities and risks for knowledge circulation in Germany arising from recent policy responses and in the light of the Lisbon Strategy can be summarised as follows:

POLICY OPPORTUNITIES:	POLICY-RELATED RISKS:
- Further improvement of the circulation of knowledge between sectors through new measures and governance mechanisms targeting co-operation between PRO and industry - Internationalisation strategy provides framework for benefiting from international knowledge	- Policy measures too strongly oriented on knowledge circulation towards established firms

Recent policies tackle all three knowledge circulation challenges and further strengthen existing strengths. It is unclear, however, to which extent they are able to address the main weakness with regard to increasing the private research base.

5.5 Summary of the role of the ERA dimension

Scientific collaboration with other European and non European countries has a long tradition in Germany. Germany's participation in the EU Framework Programme reveals a well developed network of connections. More than 80% of all EU collaborative projects involve German partners and a number of institutions are active in promoting and funding exchange programmes and/or grants for foreign researchers in Germany or for German researchers elsewhere. The new internationalisation strategy recognises the changing international landscape and related challenges. However, the European dimension and related opportunities are rather superficially covered and a European strategy is still under development.

Chapter 6. Overall assessment and conclusion

6.1 Strengths and weaknesses of research system and governance

The analysis has shown that Germany has a highly developed and well functioning research system. In each of the main domains there are strong system responses to the domain challenges (see also the summary assessment table below). Very often the responses take the form of quite stable institutional arrangements, such as the role of the German Science Foundation and the German Science Council in enhancing quality and excellence of knowledge production, or the Fraunhofer Society and the AIF in enhancing knowledge circulation to the economic sector. Any remaining weaknesses are mostly related to the adaptation and enhancement of the changes being put in place, whether this is the extent of increases in financial resources or addressing signals of cross-cutting new demand and new scientific opportunities. They are partly a reflection of the strength of the established system responses.

Domain	Challenge	Assessment of system strengths and weaknesses
Resource mobilisation	Justifying resource provision for research activities	Well established justification in terms of preserving economic competitiveness through S&T did not prevent declining share of R&D expenses in general budget
	Securing long-term investment in research	Stable mechanisms to ensure long-term research funding, but multi-level negotiations for increases are time-consuming and require political majorities difficult to achieve
	Dealing with barriers to private R&D investment	The two-thirds share of private R&D funding meets Lisbon objectives
	Providing qualified human resources	Functioning mechanisms for the provision of a strong human resource base for R&D with declining S&T graduate basis but increased attractiveness of research careers
Knowledge demand	Identifying the drivers of knowledge demand	Demand signals from classical industries well perceived by policies, but demand signals outside of these or international demand signals not well addressed
	Co-ordinating and channelling knowledge demands	Strong R&D programme basis enables a flexible response to changes in demand

	Monitoring demand fulfilment	Well established evaluation mechanisms
Knowledge production	Improving quality and excellence of knowledge production	Mechanisms in place to enhance scientific excellence of public research through DFG and Science Council. However, the rigidity of the public research system, which is strongly geared towards traditional scientific disciplines, makes it difficult to adapt to cross-cutting opportunities
	Improving exploitability of knowledge	Strong focus on research closely linked to the economy's strengths
Knowledge circulation	Facilitating circulation between different research sectors	High profile of knowledge circulation measures
	Profiting from international knowledge	Number of measures and institutions in place to ensure access to international knowledge
	Enhancing the absorptive capacity of knowledge users	Broad R&D base in the private sector ensuring good absorptive capacity, but weak dynamics with regard to new private research performers and S&T graduates

The governance structure reflects the high level of development and differentiation of the German research system (see also the related positive appraisal of the German innovation governance by INNO-Policy TrendChart, 2007). The only area in which system weaknesses are closely related to the governance structure as such is the complicated co-ordination of resource mobilisation in a federal system with shared responsibilities.

6.2 Policy dynamics, opportunities and risks from the perspective of the Lisbon agenda

The following table presents main opportunities and risks related to recent policy dynamics. It shows that recent policies since 2007 are to a large extent shaped by the implementation of major initiatives launched the years before: The Six Billion Euro programme, the High-Tech Strategy and the Initiative for Excellence address some of the main weaknesses of the German research system and hence help to create opportunities for its further evolution. Most aspects of the research-related Integrated Guideline of the Lisbon Strategy are addressed, from the 3% R&D intensity target, via the strengthening of centres of excellence and the reform of the public research base to the improvement of co-operation between PRO and industry. Although there are now first experiences with implementation, the extent of the effects of recent policies remains to be seen. An important recent policy initiative is the internationalisation strategy. It responds to the internationalisation of knowledge production by mainly also following a "strengthening the strengths" approach.

Domain	**Main policy-related opportunities**	**Main policy-related risks**
Resource mobilisation	- Increased volume of federal resource mobilisation through the "Six billion Euro programme"	- Public resource mobilisation, in particular at the Länder level, is insufficient to meet the Lisbon target - Private resource mobilisation might not respond to increased incentives to the extent anticipated
Knowledge demand	- More effective knowledge demand through better coordination between federal actors and more holistic approaches via the High-Tech Strategy	- It remains to be seen to which extent the new foresight process successfully addresses demand signals outside the classical technologies/sectors
Knowledge production	- Improved excellence and increased international attractiveness of public	-

	research enhanced by the Initiative for Excellence - Further strengthening of exploitability of knowledge by reinforced cluster approaches	
Knowledge circulation	- Further improvement of the circulation of knowledge between sectors through new measures and governance mechanisms targeting co-operation between public research organisations and industry, - Internationalisation strategy provides framework for benefiting from international knowledge	- Policy measures too strongly oriented on knowledge circulation towards established firms

Main policy-related risks are related to the domain of resource mobilisation, where despite considerable efforts at the level of federal Government, both public and private R&D funding seem still insufficient to meet the 3% target. And recent policy measures in the domain of knowledge circulation are only partially addressing weaknesses such as the seemingly stagnating absorptive capacity. It remains to be seen if the new central innovation programme for SMEs of which the first part was just launched will be able to make a difference in this respect.

The analysis of recent policies has also shown that, by and large, current German research policy priorities correspond to the strengths and weaknesses of the research system. As might be expected in highly developed research systems, issues of cross-domain integration play a more prominent role and are increasingly effectively addressed by the research policy mix. Examples include policy initiatives such as the Excellence Initiative, the High-Tech strategy, the new Cluster of Excellence initiative and the Pact for Research and Innovation, all of which systematically link increased resource mobilisation to improvements in the co-ordination of knowledge demand, knowledge production and knowledge circulation. This is partly underpinned by new governance mechanisms like the Research Union Economy – Science which is intended to contribute to the monitoring of the High-Tech Strategy. An indicator of a cross-domain perspective is also the frequency with which cluster approaches are part of the policy measures, now finding its visible expression in the Clusters of Excellence initiative launched end of 2007.

6.3 System and policy dynamics from the perspective of the ERA

The increased importance of the context of the European Research Area is acknowledged by research policy makers, e.g. in the High-Tech Strategy, and German actors are since long actively involved in shaping the ERA, e.g. as core providers and participants of pan-European research infrastructures of frequent participant of all types of FP projects. The German government has increased its involvement and visibility in the ERA-related policy debates (e.g. BMBF, 2007c).
However, this increased importance is only partly reflected both in public debates as well as in the "Strategy of the Federal Government for the internationalization of science and research" adopted early 2008 (see section 5.3 for details). The strategy recognises the changing international landscape and related challenges, but has a markedly national and global focus. The European dimension and related opportunities are rather superficially covered. A European strategy is mentioned as important element which needs further development and specification. The stated objective is

"to become a motor of European strategy development in research and innovation policy" (BMBF, 2008b, chapter 6.1) and five general guiding principles are set out. These include the strengthening of basic research, a clear focus of support instruments on performance and excellence, improvement of competitiveness, the increase of effectiveness of European co-operation with third countries and a better linkage of German research policy with European measures.

If a closer look at the four main domains is taken, it becomes evident that the role of the European Research Area, although increasing, remains still limited. The size of the national German research system, which constitutes more than one quarter of the EU research area, is an important explanatory factor. Regarding resource mobilisation for research, the research-related elements of the Lisbon strategy were instrumental for the Government to prioritise the 3% target and to increase funding at federal level. Germany funds and participates actively in all important pan-European infrastructures and European mobility initiatives. The share of the EU Framework Programme is with less than 2% of total German R&D funding rather limited. There is a wide range of mobility initiatives, but still mainly driven by the national context. However, Germany was one of the first countries which transposed the VISA directive for scientists into national immigration law.

A similar picture emerges for the direct effect of European Union activities on national research priority setting. Care is taken to ensure that national priorities are sufficiently reflected in European programmes, and FP and national main thematic areas do generally coincide. German actors are also present in practically all ERANETS. However, there is an indirect impact of European priorities on research actors. Beyond the EU level, there are intensive bilateral relationships between Germany and France which also cover the R&D domain. Attempts of joint programming beyond a matching of related project activities are however limited.

German research actors are participating in all ERA initiatives. Processes to ensure excellence and exploitability of knowledge production still follow mainly a national logic. There are some signs of change with the Initiative for Excellence and the new cluster competition which both highlight the international dimension as benchmark.

Scientific collaboration with other European and non European countries has a long tradition in Germany. More than 80% of all EU collaborative projects involve German partners and a number of institutions are active in promoting and funding exchange programmes and/or grants for foreign researchers in Germany or for German researchers elsewhere. According to the ERAWATCH Research Inventory, foreign participation in national research programmes is possible in a number of programmes. For funding there is the principal option to use subcontracting. Some limited experiences with joint programming exist, in particular with France, but legal and other barriers to the merging of funds and differences in the institutional structure of the research systems make implementation a challenging task.

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Abbreviations

AiF: Arbeitsgemeinschaft industrieller Forschungsvereinigungen "Otto von Guericke" (German Federation of Industrial Research Associations)
BERD: Business Expenditures on R&D
BMBF: Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research)
BMWA: Bundesministerium für Wirtschaft und Arbeit (Federal Ministry of Economics and Labour)
BMWI: Bundesministerium für Wirtschaft und Technologie (Federal Ministry of Economics and Technology)
CERN: European Organization for Nuclear Research - European Laboratory for Particle Physics
DAAD: Deutscher Akademischer Austauschdienst (German Academic Exchange Service)
DFG: Deutsche Forschungsgemeinschaft (German Research Foundation)
ERA: European Research Area
ESA: European Space Agency
FhG: Fraunhofer Gesellschaft (Fraunhofer Society)
FP: Framework Programme
GWK: Gemeinsame Wissenschaftskonferenz (Joint Science Conference)
HGF: Helmholtz-Gemeinschaft Deutscher Forschungszentren (Helmholtz Association)
ILL: Institut Laue-Langevin
IPR: Intellectual property rights
ISL: Institut Franco-Allemand de Recherches de Saint-Louis
ITA: Innovations- und Technikanalysen (Innovation and Technology Analyses)
MPG: Max Planck Gesellschaft (Max Planck Society)
WGL: Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz (Leibniz Association)
ZIM: Zentrales Innovationsprogramm Mittelstand (Central Innovation Programme for SMEs)

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Abstract

The main objective of ERAWATCH country reports 2008 is to characterise and assess the performance of national research systems and related policies in a structured manner that is comparable across countries. The reports are produced for each EU Member State to support the mutual learning process and the monitoring of Member States' efforts by DG Research in the context of the Lisbon Strategy and the European Research Area. In order to do so, the system analysis focuses on key processes relevant for system performance. Four policy-relevant domains of the research system are distinguished, namely resource mobilisation, knowledge demand, knowledge production and knowledge circulation. The reports are based on a synthesis of information from the ERAWATCH Research Inventory and other important available information sources.
This report encompasses an analysis of the research system and policies in Germany.

The mission of the Joint Research Centre is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of European Union policies. As a service of the European Commission, the Joint Research Centre functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

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