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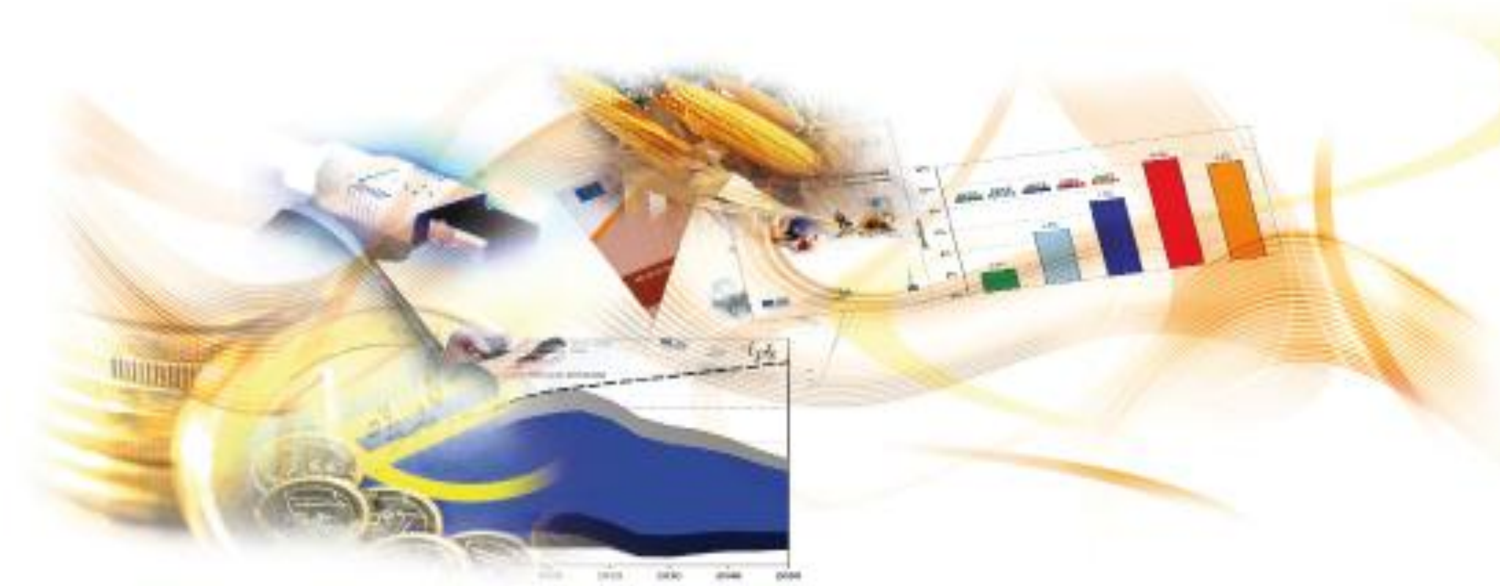

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The Country Report 2012 builds on and updates the 2011 edition. The report identifies the structural challenges of the national research and innovation system and assesses the match between the national priorities and the structural challenges, highlighting the latest developments, their dynamics and impact in the overall national context.

The first draft of this report was produced in December 2012 and was focused on developments taking place in the previous twelve months. In particular, it has benefitted from the comments and suggestions of Jörg Zimmermann from JRC-IPTS. The contributions and comments from Federal Ministry of Education and Research are also gratefully acknowledged.

The report is currently only published in electronic format and is available on the ERAWATCH website. Comments on this report are welcome and should be addressed to jrc-ipts-erawatch-helpdesk@ec.europa.eu.

EXECUTIVE SUMMARY

In terms of both population and GDP, Germany is the biggest country within the EU. Given the current Eurostat forecasts for 2012, Germany stands for about 20.6% of the total EU-27 GDP, i.e. the GDP per capita is estimated to be about 27% above the EU-27 average. Yet, over the recent years, also the economic figures of Germany were affected by the economic and financial crisis. However, Germany recovered rapidly and returned to growth in GDP (2010: +4.2% and 2011: +3.0%); i.e. the German GDP has surpassed already in 2011 the pre-crisis level. Nevertheless, in the light of the slowdown of the global economy and the uncertainties concerning the Euro, the estimated growth figures for 2012 are down to just 0.8% (even negative in the 4th quarter of 2012), but overall remain still well above the forecasted EU-27 average for 2012 (-0.3%). Moreover, the current estimates assume acceleration in the annual German GDP growth for 2013 and 2014 (0.9% and 2.2%, respectively).

Germany also has the largest research system in the EU. GERD was about €67.0b in 2009 and further increased to €69.9b in 2010 and €73.7b in 2011. Thus, Germany contributed 28.7% to the overall EU-27 R&D expenditure in 2011 (i.e. the share increased by 0.3 percent points compared to 2010). It is remarkable that public funding of R&D was not decreased during the years of crisis. In fact, GBAORD even rose between 2008 and 2010 by about 17% to €23.0b in 2010 and grew in 2011 by another 1.8% to a total spending of €23.4b. The increase in public R&D funding offset the slight decline in R&D investments of the business sector in 2009 (BERD: -1.7%). In 2010, BERD begun to rise again by 3.7% (total BERD €46.9b), followed by an increase of even 5.1% in 2011 (total €49.3b). The share of private R&D/GDP thus remained about constant at 1.9%, i.e. the business enterprise sector performs about two-thirds of total R&D in Germany (67% in 2011 compared to 65.6% in 2010).

Looking at 2012 and beyond, government budget provisions for R&D and innovation kept increasing in course of 2012 although GDP growth has slowed down and are announced to be further rising in 2013. Provisional indicators from the business sector point into the same direction and give reason to assume that the overall R&D and innovation spending in Germany will be going up in the years to come. Policy has supported this trend by a series of economic stimulus packages and strategic initiatives such as the HTS-2020[1] (see e.g. HTS-Action Plans launched in 2012). Germany thus underlines its long-term commitment towards an R&D and innovation driven policy.

According to the Innovation Union Scoreboard (IUS) 2011, Germany is among the 'Innovation Leaders' in Europe (together with Sweden, Denmark and Finland), ranked overall at position three within the EU-27. 'Intellectual assets and innovators' are particular strengths of the German system (with above average growth rates) while relative weaknesses are seen in 'human resources'; concerning 'open, excellent and attractive research systems'; 'finance and support'; and in terms of 'linkages & entrepreneurship'. Furthermore, lately a strong decline was observed for the German IUS-2011 indicators capturing non-R&D innovation expenditure. In contrast, significant improvement was observed for Community trademarks, license and patent revenues from abroad and international scientific co-publications.

R&D and innovation policy is among the top priority areas of both federal and state governments without significant changes in perspective and/or policy approach over the last couple of years. Also among the group of main policy actors and institutions involved within the governance of the research system, there have been no major changes in recent years. The same holds

1 The main aims of the HTS are to create lead markets, intensify cooperation between science and industry, and to continue to improve the general conditions for innovation. With the proposed directions and instruments, basically all structural challenges can be addressed.

for the set of policy instruments in place. In fact, R&D and innovation policy in Germany is quite persistent and straightforward. However, some shifts in priority settings and individual policy initiatives have occurred, mainly towards rather mission-oriented approaches in technology policy (see e.g. the setup of future-oriented projects as part of the HTS-2020' Action Plan[2]). In general, ongoing (structural) reforms were continued in course of 2012, especially the '*Exzellenzinitiative*' (outlook: continue as before) and the '*Pakt für Forschung und Innovation*' (outlook: further expanding). Newly introduced in 2012 are e.g. the "Freedom for Science law" (*Wissenschaftsfreiheitsgesetz),* which aims at making the budgetary rules of (publicly co-financed) non-university research institutions more flexible, and the "Foreign Skills Approval/Recognition law" (A*nerkennungsgesetz*), which creates a legal entitlement to claim for recognition of foreign vocational education. Moreover, a draft for changing the German Basic Law has been put forward (*Grundgesetz*, Artikel 91b) which seeks to change the current regulation in terms of financing universities (in particular joint initiatives of federal and state level). However, the initiative is still subject of a controversial political debate.

Finally, a number of further initiatives are on the way (see BMWi: new innovation strategy "Making the most of technology") as e.g. smart specialisation by strengthening co-operations between businesses and research institutes as well as business driven innovation clusters and enabling them to emerge as excellence centres recognised at regional and European level. Moreover a new competence centre for procurers will be open from 1 March 2013 to stimulate the demand for innovations. Regional RIS3 on smart specialisation are due to be developed but so far are not available for all states. In this regard, evidence suggests that the corresponding ex-ante conditionality of the EU structural funds pushes some regions (more than others) to advance their RIS3 concepts.

The key priorities of research and innovation policy in Germany continue to be: (i) keeping pace with global technology trends, (ii) ensuring/providing sufficient funds for public and private R&D and thus keeping research excellence at a top international level, (iii) maintaining and further improve the industry-science link (i.e. enabling knowledge flows at the public~private nexus), and (iv) strengthening the education sector (at all levels) in order to stimulate knowledge creation, capability building, absorptive capacities and ultimately the formation of a qualified workforce.

The main challenges that Germany is confronted with in the area of research and innovation are the expansion of research in cutting-edge technologies, the provision of sufficient funding for R&D, the commercial exploitation of scientific knowledge, the provision of a qualified workforce, and responding to the new energy concept through 'green' energy (see chapter 4.3 for more details). The current policy mix addresses these challenges through a broad range of measures. In particular:

- Keeping pace with global technology trends by expanding research in cutting-edge technologies (e.g. by means of thematic R&D programmes and innovation alliances; all embedded in the HTS-2020) as well as by supporting its adaptation. Moreover, stimulating the creation of lead markets is another (recent) approach to address societal challenges and to gear increasingly towards high-tech sectors which are expect to have significant growth potential.
- Ensuring sufficient funds for public and private R&D and thus keeping research excellence and innovativeness at a top international level. In fact, access to finance for R&D and innovation in Germany is still limited and appears to be a barrier especially for the business sector (SMEs, NTBF, small/young innovators, etc.). The HTS-2020 recognises this challenge and a number of measures seek to address this issue, for instance the increased focus on

2 The general aim is to bundle the innovation relevant policies and initiatives of all federal resorts and also to bring together the efforts made at HEI/PRO and business sector, particularly in the fields of climate/energy, health/healthy food, mobility, communication, and security

SMEs in public R&D programmes ("SME innovative", "ZIM", etc.) and the expansion of the provision of VC through "High-tech Start-up Fund II". A new instrument to support venture capital "*Investitionszuschuss Wagniskapital*" will be introduced in 2013.

- Maintaining and further improving industry-science links and by that means stimulating the commercial exploitation of scientific knowledge. This is one of the core points in the HTS-2020, implemented e.g. by the initiatives VIP - "*Validierung des Innovationspotenzials wissenschaftlicher Forschung*" (validation of innovation potentials of scientific research", "Spitzencluster-Wettbewerb" (leading edge cluster competition) and "Forschungscampus"These measures may also contribute to the evolvement of high-tech sectors.
- Strengthening the education sector at all levels in order to stimulate knowledge creation, capability building, absorptive capacities, and thus ensuring the provision of a qualified workforce. In fact, the German education system still exhibits a number of challenges (performance lacking behind compared to other leading EU/OECD countries) and is constraint by too complex policy coordination. Moreover, existing/potential resources need to be mobilised to a larger extent (women, foreign-born residents, immigrants). A number of initiatives are launched to address these points, such as e.g. "Pact for Higher Education", "Initiative for Excellence", and "Qualification Initiative".
- Fostering research and innovation in energy supply and thus responding to the new German energy concept which implies the nuclear phase-out until 2022. To secure the energy supply afterwards, further research and innovation activities are necessary. The expansion of the high-tech sector could contribute to cope with this challenge. A broad range of support programmes by various ministries were launched in this regard, e.g. the "6. Energy Research Programme" (with an overall budget of €3.5b for 2011-2014) and the "Integrated Energy and Climate Programme" (IEKP) aimed at increasing energy efficiency and stimulating the adaptation of renewable energy technologies.

Looking from an EU-27 wide perspective, although there is no explicit strategy towards ERA, Germany has developed in the last years a strategic thinking and action towards the ERA. There is a strong involvement of national policy makers in the five ERA-Initiatives and other European issues. EU level instruments are being used for national goals, and there are attempts to influence the European level policy with core ideas as set out in the Internationalisation Strategy and the High Tech-Strategy 2020. Triggered by a broadening of R&D policy and innovation policy at EU level, there have been steps towards a more functional "horizontalisation" at national level, i.e. European involvement is becoming part of the strategic thinking and there is a stronger awareness of European issues across all ministries (e.g. visible in ERA-Net participations). However, there remain several challenges when it comes to maximise the benefits of the ERA development for Germany and contributing to an optimised ERA development. Not all of them can be addressed by the German federal government, which however, can take a leading or at least supporting role. In fact, the German Expert Commission on Research & Innovation points out that the federal government could intensify its role in the European coordination process and take a lead in the area of research and innovation in order to shape the ERA (EFI, 2011; re-emphasised in EFI, 2012).

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1 INTRODUCTION

In terms of both population and GDP, Germany is the biggest country within the EU-27. With 81.8 million inhabitants in 2012, 16.2% of the EU-27 total population of 503.7 million live in Germany. Thus, according to the Gross Domestic Product (GDP) forecasts for 2012 (€2,646b and €12,817b for Germany and the EU-27, respectively), Germany stands for about 20.6% of the total EU-27 GDP. Germany's GDP per capita for 2012 is estimated to be 27% above the EU-27 average.[3]

Over the recent years, like in many other industrial economies in the world, the economic figures for Germany were affected by the economic and financial crisis. While in 2008 a moderate increase in real GDP could still be realised (+1.1%), in 2009 it sharply declined (-5.1%). However, Germany recovered rapidly from the crisis and returned to growth, realising an increase of 4.2% in 2010 and 3.0% in 2011, and by that means meanwhile has surpassed already the pre-crisis level. Nevertheless, in the light of the global economic slowdown and the uncertainties concerning the Euro, the estimated growth figures for 2012 are down to just 0.8%, but however remain still well above the forecasted EU-27 average for 2012 of -0.3%.

Germany also has the largest research system in the EU (measured in terms of gross R&D expenditure (GERD)). Germany's GERD was about €67.0b in 2009 and further increased to €69.9b in 2010 and €73.7b in 2011. Thus, Germany contributed 28.7% to the overall EU-27 R&D expenditure in 2011 (i.e. the share increased by 0.3 percent points compared to 2010). It is remarkable that public funding of R&D was not decreased during the years of crisis and economic downturn. In fact, the GBAORD even rose between 2008 and 2010 by about 17% to €23.0b in 2010 and grew in 2011 by another 1.8% to a total spending of €23.4b. The increase in public R&D funding offset the slight decline in R&D investments of the business sector in 2009 (BERD: -1.7%). In 2010, BERD begun to rise again by 3.7% (total BERD €46.9b), followed by an increase of even 5.1% in 2011 (total €49.3b). The share of private R&D/GDP thus remained about constant at 1.9%, i.e. the business enterprise sector performs about two-thirds of total R&D in Germany (67% in 2011 compared to 65.6% in 2010).

According to the Innovation Union Scoreboard (IUS) 2011 (which measures and compares the innovation performance across the EU-27), Germany is among the 'Innovation Leaders' in Europe (together with Sweden, Denmark and Finland) ranked overall at position three within the EU-27 and is thus well above the EU-27 average (see IUS-2011, p. 7). Intellectual assets and innovators are particular strengths of the German system (with above average growth rates) while relative weaknesses were found in terms of human resources[4]; concerning 'open, excellent and attractive research systems' (although the indicators in this regard seem to be improving with growth rates well above EU-27 average, i.e. Germany is catching up); finance and support (e.g. below average volume of Venture Capital (VC)); and in terms of linkages & entrepreneurship (especially with respect to collaboration of innovative SMEs). Furthermore, lately a strong decline was observed for the German IUS-2011 indicators capturing non-R&D innovation expenditure. In contrast, high growth (fast improvement) was observed for Community trademarks, license and patent revenues from abroad and international scientific co-publications.

Germany's research system is grounded in a well-established university system and a large and unique non-university public research system. The latter is mainly based on the four large research organisations: Max Planck Society (MPG), Fraunhofer Society (FhG), Helmholtz Association (HGF), and Leibniz Association (WGL).

3 If not referenced otherwise, **all quantitative indicators are based on EUROSTAT data**.

4 Education level was evaluated as partly below Eu-27 and OECD averages and, moreover, the attractiveness for scientific workforce was found to be comparably low.

As indicated by data on publications and patents as well as by a range of system evaluations conducted during the last decade, the German research system demonstrates a strong capacity for producing scientific and especially technological knowledge. For instance, regarding the number of citations of scientific publications produced by German researchers, Germany belongs to the leading group of countries at global scale by taking third place in total ((1)USA: ca. 115 million citations between 1996 and 2011, (2) UK: ca. 28m, and (3) Germany: ca. 23m).[5] In terms of triadic patents, in average about 12.6% of all patents from OECD countries are filed from Germany while the share of the entire EU-27 was 30% (WR, 2010).[6]

The industrial innovation system in Germany is characterized by a strong specialisation on medium-/high-tech manufacturing, such as automotive, mechanical engineering and chemicals. Within the business enterprise sector, the largest demand for knowledge is in the automotive sector as revealed by the amount of in-house R&D expenditure (in 2010, about 32% of total business enterprise expenditure on R&D (BERD)). Other important sectors are the electronics and electrical industry (including instruments) which spent €7.3b in 2010 to finance intramural R&D (16% of total) and the chemical and pharmaceutical industries (€6.9b, 15%). A further relevant source is the mechanical engineering sector (€4.6b, 10%).[7] Overall, German enterprises are strongly oriented towards an innovation-based competitive strategy, revealed by a high share of innovating enterprises (2010: 48%) and a high share of enterprises that conduct in-house R&D (23%; see: Rammer et al., 2012).

Due to the federal structure, both the federal government and the 16 federal state (*Bundesländer* or just "*Länder*") governments are important players in terms of Germany's research and innovation policy. The federal government takes up a variety of activities in research and innovation policy and may be regarded as the main state actor in the German system. The Federal Ministry of Education and Research (BMBF) have the nationwide responsibility for research policy. The Federal Ministry of Economics and Technology (BMWi) is responsible for innovation and technology policy as well as for some areas of R&D policy. In addition, several other ministries maintain their own research institutes in order to fulfil their demands for evidence based governance (*Ressortforschungseinrichtungen*).

Education policy lies almost exclusively within the responsibility of the individual *Länder*. The *Länder* governments' main activity in research is to fund universities and co-fund the four large research organisations. Moreover, they are engaged in non-university-related R&D funding and innovation activities (see e.g. BioRegio-initiatives). In addition, they are involved in science-industry linkages and innovation programmes. There are also a number of joint activities of the federal and state governments, e.g. joint institutional funding of the four main research organisations and the programme for the Academies of Sciences. The Joint Science Conference (GWK) is the main body that coordinates research policies between the federal government and the state governments.
Most publicly funded R&D programmes are administered and managed by a range of implementation agencies (*Projektträger*), with some of them located within large research centres.

The German Science Foundation (DFG) is the self-governing organisation for science and research in Germany and serves all branches of science and the humanities. The chief task of the

5 Data according to Scopus, see Scimago Lab <link>. Please note: Germany's ranking might be slightly different if the order is based on an indicator defined differently, for instance, number of total / citable documents, number of citation per document, etc.

6 For further figures see e.g. Innovation Union Competitiveness Report – Germany 2011.

7 The forecasted sector shares for 2011 and 2012 (thus in contrast considering intra-mural R&D expenditures only) appear to be virtually the same, but figures are rising in absolute terms. See: Stifterverband, 2011. <link>

DFG is to select the best research projects by scientists and academics at universities and research institutions on a competitive basis and to finance these projects.

The German Federation of Industrial Research Associations "Otto von Guericke" (AiF) deals with the promotion of applied R&D for the benefit of small and medium-sized enterprises (SMEs).

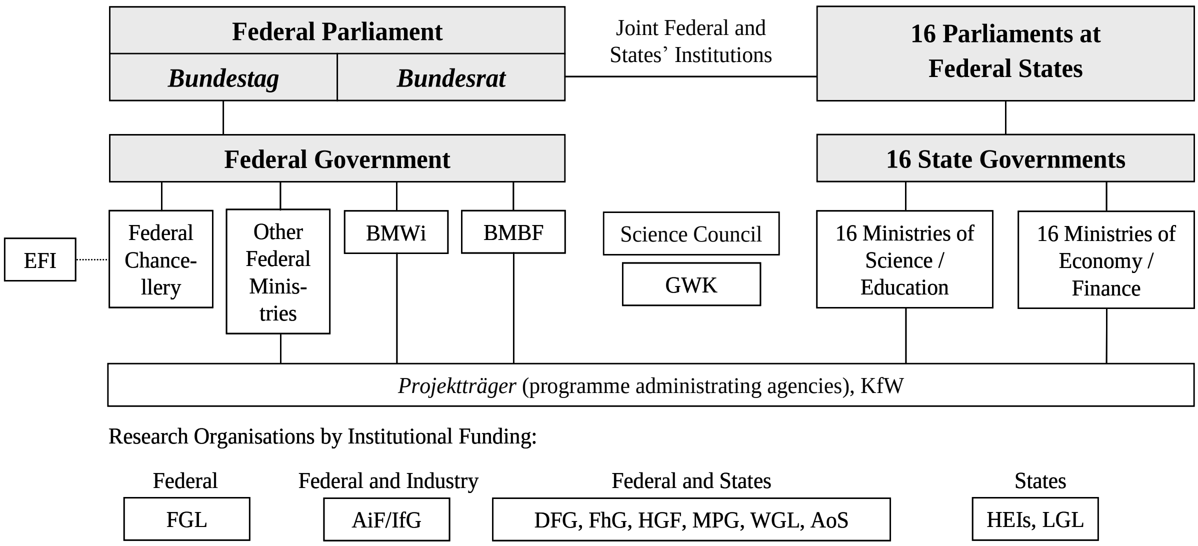
With regard to the governance of the research system in Germany, there have been no major changes in recent years among the group of main policy actors and involved institutions. However significant efforts have been made to increase interconnections between the institutions. In general, research in Germany is conducted by a diverse spectrum of performers. Measured by international standards, the business enterprise sector is thus a comparably strong R&D performer. In fact, as outlined above, private R&D performers are responsible for about 2/3 of Germany's total R&D expenditures (GERD). In particular large enterprises play an important role. Companies with more than 500 employees account for around 84% of intramural R&D investments of the business sector (BERD; Stifterverband, 2011).[8] In turn, the ~400 Higher Education Institutions (HEIs) in Germany performed in 2010 about 18.0% of total R&D expenditure (GERD). A unique feature in Germany is a wide range of Public Research Organisations such as MPG, FhG, HGF and WGL with a large number of institutes, covering the whole spectrum from fundamental and applied research to research services. They performed 14.7% of GERD in 2010, i.e. their quantitative significance in the German research system is almost comparable to that of universities. The special role of PROs in the German research and science system is to provide long-term oriented research based on large research infrastructures (covering technical as well as data and informational infrastructure) and to offer top scientists space for concentrating on research. Another relevant block of public research performers consists of governmental research agencies and institutes (*Ressortforschungseinrichtungen*). These institutions provide ministries with scientific knowledge and administer sovereign tasks such as the compliance of quality and safety standards.

Despite the clear separation in statistics between HEIs on the one hand and PROs on the other, both sectors are closely interlinked in practice. In all MPG institutes and the vast majority of FhG, HGF and WGL institutes, directors of institutes are at the same time full professors at universities and hold university chairs. All four large PROs are actively engaged in graduate and post-graduate education.

See below a chart illustrating the structure of the German research system (Figure 1).

8 For more detailed information concerning company level investment trends in R&D see, for instance, the EU Industrial R&D Investment Scoreboard <link>, most recent version released on Dec 6th 2012.

Figure 1 : Organisational chart of institutions in the field of research and innovation in Germany



BMWi:	Federal Ministry of Economics and Technology	DFG:	German Research Foundation
BMBF:	Federal Ministry of Education and Research	AiF:	Association of Industrial Research Institutes
FhG:	Fraunhofer Society	IfG :	Institutes of Co-operative Industrial Research
MPG:	Max Planck Society	KfW:	KfW Banking Group - State-owned bank (80 % Federal Government, 20 % States)
WGL:	Leibniz Association	GWK:	Joint Science Conference of the Federal Government and the Federal States
AoS:	Academies of Sciences	LGL:	Länder Government Research Organisations (State Agencies, other research institutions funded through State governments)
HEIs:	Higher Education Institutions		
FGL:	Federal Government Research Organisations (Federal Agencies)	EFI:	Expert Commission on Research and Innovation

Source: ERAWATCH - Germany CR-2011; PRO-INNO Mini Country Report – Germany, 2011.

2 RECENT DEVELOPMENTS OF THE RESEARCH AND INNOVATION POLICY AND SYSTEM

In Germany, in the light of the financial and economic crisis, the consensus has been reinforced that innovation, as well as investment in the capacity to innovate, is central for recovery and a number of further social goals. There is now indeed a greater recognition of the need to move towards new, more inclusive and environmentally sustainable models of growth. In fact, it is not only the rate of technical change but also its direction (in applications, uses and solutions) that can help to address the grand societal challenges. However, notable changes in terms of vision of R&D and innovation policy and even more in the established R&D&I system takes time and commonly evolve rather gradually than ad hoc. Accordingly, when reflecting developments of the corresponding policies and trends possibly pointing towards a system change, one has to consider a wider time span than 1 year (which is set out as the natural horizon of a yearly Country Report like this). Hence, in this section the most recent developments shall be considered in the context of the changes that occurred during the last couple of years, thus seeking to understand where political emphasis is enforced or removed, what are adjustments of existing instruments, and where eventually a new line and/or a new direction of efforts emerges (i.e. changes in policy instruments, policy mix, and/or systemic changes).

2.1 National economic and political context

Innovation policy has been among the priorities of the German federal government for several decades. The prominent position of this policy area has been reinforced by releasing a new white paper: the High-tech Strategy 2020 (HTS-2020). Launched in July 2010, the strategy continues a first initiative from 2006 and follows a mission-oriented approach to innovation policy, thus aiming at encouraging a shift towards cutting-edge technologies in the context of an overall objective of strengthening the innovation efforts of as many companies as possible. In contrast to its predecessor, the new strategy focuses on five priority fields on which R&D and innovation efforts shall be targeted in the next decade, namely: climate/energy, health/nutrition, security, mobility, and communication. As a new element, so-called future-oriented projects *(Zukunftsprojekte)* are introduced. These projects define and pursue specific objectives related to one of the five priority fields over a period of 10 - 15 years. In the context of the HTS-2020, recently two new measures have been introduced both aiming at facilitating cooperation between industry and academia: (1) the scheme 'Validation of Innovation Potentials' which offers grants to researchers at universities and PROs to further investigate the commercialisation prospects of their research findings and (2) the programme "*Forschungscampus*" which provides funding for long-term oriented cooperation between universities, PROs and private businesses.

Overall, it can be stated that the main structure of the research and innovation budget in Germany has not changed much over the past years. There was also no significant change in the share of the budget provided by different funding sources (federal, state, abroad). This is remarkable in the light of the economic downturn in Europe. In fact, also the growth figures for Germany recently have been decreasing (after 3.0% in 2011, down to estimated 0.8% in 2012, with current forecasts of 0.9% and 2.2% for 2013 and 2014, respectively). Nevertheless, by a series of strategic initiatives such as the HTS-2020 (see below for more details on recently launched Action Plans) and, in parallel, overall rising budget provisions for public spending on / support to R&D and innovation,[9] Germany underlines its long-term commitment towards an R&D and innovation driven policy.

In addition, the types of funding mechanisms in terms of grants, venture capital, subsidised loans, tax incentives, guarantees etc. did not change either. In turn, demand-side innovation policies are gaining increasingly attention in Germany. The above mentioned new HTS-2020 Strategy may be seen as a specific approach to link demand for innovation with technology producing capacities.[10]

Direct subsidies to users of innovations, are regarded in Germany as a less efficient instrument.[11] Much more important are regulations, particularly in the field of environmental policy. Public procurement has received increasing attention, though there is still an ongoing debate about the effectiveness of the state as a lead user.

Another controversial debate concerns Germany's education policy, especially the reform of federalism *(Föderalismusreform I)*, which was enforced in September 2006[12] The reform provided for an abolition of the joint tasks of "construction in the higher education sector" and "education planning", both of which had been anchored in the German Basic Law (*Grundgesetz*, GG). Prior to the Federalism Reform I, the federal government had been allowed to co-finance building projects in the higher education sector by covering 50 percent of construction expenses. To compensate for the increased burden on the *Länder* caused by the cancellation of these joint tasks, the federal government's share of contributions stipulated for university construction has been made available to the *Länder* until and including 2019, while funding is earmarked until 2013. Construction of tertiary education research facilities and large-scale equipment remained to be a joint task and thus eligible for co-financing of *Bund* and *Länder*.

The reform of 2006 left the joint tasks untouched that enables policy-makers from the federal and *Länder* levels to co-operate in the area of research ventures of trans-regional importance such as for instance the MPG (Max-Planck-Gesellschaft) DFG (Deutsche Forschungsgemeinschaft) and FhG (Fraunhofer-Gesellschaft). The reform of 2006 introduced a new joint task regarding temporary projects allowing *Bund* and *Länder* to promote science and teaching at universities. This joint task requires that all of the 16 *Länder* give their consent. This newly introduced joint task provided the framework for a number of very successful initiatives like the "Higher Education Pact", "Initiative for Excellence" and the "Quality Pact for Teaching".

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9 Public funding of research and innovation in Germany has increased significantly over the past five years. In 2010, total government spending (federal + States) for research and innovation was about €39b (further rising budget provisions announced). The bulk of funding thus goes to universities (about €20b, including public funding for tertiary education programmes) and public research organisations (about €10b, including funding for generic scientific programmes). Technology-specific R&D programmes (including defence R&D programmes and international technology programmes) amount to about €7b. Generic R&D programmes targeting enterprises and R&D cooperation had a budget of almost €2b.

10 Demand-side innovation policies in Germany strongly focus on early interaction between potential users of new technology and those actors that develop technology. Interactions should facilitate mutual learning and help to introduce technologies that meet the requirements of future markets. In this respect, lead market initiatives have been used from the early 2000s onwards. The so-called forward-looking projects of the High-tech Strategy 2020 pursue this policy approach.

11 Tax credits have been the subject of a political discussion as an instrument for stimulating corporate R&D. However, for a series of reasons (incl. household consolidation), in contrast to many other countries, a corresponding scheme is not implemented in Germany (yet?).

12 The aim of the Federalism Reform was to eliminate excessive links between federal and state levels (*Bundesrat*, 2006: p. 17). With the passing of the law on 28 August 2006, Article 91a, Paragraph 1 (1) of the Basic Law was abolished. In addition to that, Article 91b of the Basic Law was revised.

A number of voices from the fields of science and politics have been pleading for the necessity to further adjust Germany's federal structure, arguing that the federal government should be re-enabled to provide long-term institutional funding for universities. An Expert Commission assessing the German research, innovation and technological performance strongly agrees with this plea (see: EFI – 2012, p. 35). Some political efforts to address the mentioned imbalances have been made (see briefly discussed in chapter 2.3). However, as changing the basic law requires a 2/3 majority in the parliament as well as in this case consent in the *Bundesrat* (chamber of regions), it appears unlikely that this issue will be solved easily in the nearer future (most likely not before the next general election scheduled for 09/2013).

2.2 Funding trends

The budgets for research and innovation in Germany have expanded remarkably over the past three years (looking at both the public as well as private sector figures). For instance, the federal government budget earmarked for R&D and innovation rose from a total of €16,883.9 million in 2011 to €17,665.0 million in 2012 (budget provisions) mainly driven by the increase in innovation support of about 20% from €3,203.8 in 2011 to a total of €3,846.8 million in 2012 (R&D support: €13,680.1 and €13,818.2 million in 2011 and 2012, respectively). Moreover, according to the federal government budget provision for 2013, the budget tentatively allocated just to the ministry of education and research (BMBF) is expected to rise even further by 6.2% compared to 2012 to an overall of €13.7b (accumulated budget increase from 2010 until 2013: €13.3b); see <link>). All these changes were triggered by the new High-tech Strategy[13] which was accompanied by an additional €6b funding effort (for the legislation period 2010 – 2013).[14] Moreover, in 2009 and 2010, a series of economic stimulus packages also contributed to higher research and innovation budgets.

At the side of the *Länder*, research and innovation budgets were mostly stable or slightly shrinking since a number of years, although this changed somewhat after 2009 when also many state governments engaged in anti-crises activities and established stimulus packages. In addition, reform of higher education curricula (bachelor and master studies), the increase in the number of students due to a shortening of secondary school time, and an expected further rise due to the abolition of compulsory military service in 2011 have urged state governments to increase funding for higher education institutions.[15]

Despite the economic and financial crisis, overall R&D expenditures kept increasing, although at a lower rate. In terms of R&D expenditures, Germany remains to be the country with the largest research system in the EU: GERD was €67.0b in 2009 and further increased to €69.9b and

13 In 2013, the support to projects tackling the grand societal challenges as provided by the Hightech-Strategie HTS-2020 will increase to €2,3b, which is equivalent to +24% compared to 2009 and even + 90% compared to 2005.

14 Source: Bildung und Forschung in Zahlen, p. 14 (Table 9). Note that the federal government decided to increase the budget earmarked for R&D, innovation and education over the current legislation period 2010 – 2013 by €12b (of which €6b were allocated to R&D and innovation related activities as specified in the jointly released new HTS-2020).

15 Based on the *Qualitätspakt Lehre*, in year 2013, an extra of €200 million is foreseen to be invested by the BMBF into the improvement of framework conditions and the general quality of higher education. Moreover, as part of the *Hochschulpakts 2020, the Länder* will receive €1.85b for creating extra student places in 2013. BMBF ressources for *Exzellenzinitiative* and the *Programmpauschalen* add up in 2013 to a total of €680m mean to improve research at universities. In the same regard, the means provided to HEI as part of the *Pakt für Forschung und Innovation* will increase by 5% annually (i.e. also in 2013). Further points addressed by the BMBF are vocational training (special focus on disadvantaged kinds and youth; increase in spending in 2013 of 16%, i.e. €214m), long life learning (+26.5%).

€73.7b in 2010 and 2011, respectively. Thus, Germany contributes significantly to EU resource mobilisation, being responsible for 28.7% of aggregate EU-27 R&D expenditure in 2011 (+0.3% compared to 2010).

It is remarkable that public funding of R&D was not decreased during the crisis. GBAORD increased between 2009 and 2011 by 12.5% to about €23.4b in 2011. The business sector (BERD), after a drop in 2008, has surpassed the pre-crisis level in terms of R&D spending already in 2010[16] and investments increased further in 2011 (+7% compared to 2008). Business sector R&D intensity (BERD as % of GDP) reached approximately 1.9% in 2011. The percentage of GDP invested in R&D in Germany increased from 2.69% in 2008 to estimated 2.84% in 2011 (EU average 2.0%) with the business enterprise sector standing for about two-thirds of total R&D in Germany (67% in 2011 compared to 65.6% in 2010).

Table 1: Germany R&D funding figures in detail

	2009	**2010**	**2011**	**2012** (estimate, if such data is available)	**2020 national target**	**EU average 2011**
GDP growth rate	-5.1	4.2	3.0	0.8	:	1.5
GERD as % of GDP	2.82	2.80	2.84[e]	:	3.0	2.03[s]
GERD (€ million)	67,015	69,948	73,692[e]	:	:	256,586.5[s]
GBAORD as % of GDP	*0.88*	*0.92*	*0.90*	:	:	*0.75*
GBAORD (€ million)	20,833	23,016	23,437[p]	:	:	*92,308*
BERD as % of GDP	1.91	1.88	1.9[p]	:	:	1.27[s]
BERD (€ million)	45,275	46,929	49,342[p]	:	:	159,975.9[s]
R&D performed by government sector (% of GERD)	29.8	30.3	n.a.	:	:	n.a.
R&D performed by higher education sector (% of GERD)	*17.6*	*18.1*	*18.3*[e]	:	:	*24.0*[s]
R&D performed by PROs (% of GERD)	*14.8*[e, DE]	*14.7*[e, DE]	*n.a.*	:	:	n.a.
R&D performed by Business Enterprise sector (% of GERD)	66.1	65.6	*67.0*	:	:	*62.3*
R&D performed from abroad (% of GERD)	3.8	3.9	n.a.	:	:	n.a.
Share of competitive vs. institutional public funding for R&D[#, DE]	46.2 / 44.2	*49.5 / 41.6*	*51.4 / 40.6*	*49.6 / 42.5*		n.a.

p=provisional, s=Eurostat estimates, e=estimated, n.a.='not available', :='no figure'
DE: Data provided by German Statistical Office / BMBF
'Italic': own calculations based on figures provided by statistical offices

[#] The German system of public R&D funding is based on two pillars: institutional funding and project funding. While institutional funding is provided to cover the basic financial demands of public research institutes and universities as well as the costs of R&D in areas with low significance of third-party funding (basic research), project funding is target-oriented and has a short to medium-term focus. See BMBF (2012) – Bundesbericht fuer Forschung und Innovation, pp. 430ff for further details concerning the corresponding figures presented above in Table 1.

Sources: Eurostat, <link>: Last update 22/12/2012
German Statistical Office (Statistisches Bundesamt) and BMBF <link>: last update 07/12/2012

As agreed at the Dresden Education Summit (*Dresdner Bildungsgipfel*) on 22 October 2008, the goal of the federal government and the states is to raise spending levels for education and research to 10% of GDP by 2015, including the 3 %-target for R&D.. Thus, two-thirds of the R&D target should come from the private sector and one-third from the public sector. Germany makes steady progress to achieve these targets.

16 Innovationserhebung 2011 (ZEW, 2012 <link>).

The main challenge for the next years will be to maintain the growth path in research and innovation budgets. In the past years, HEIs and PROs primarily profited from increased funding. In the years to come, budgets need to be reallocated in some way to allow for an increased funding of enterprises and co-operative projects, too, especially in those fields of technology where the need for technical progress is particularly high (e.g. energy technologies, E-mobility, health, resource efficiency).

2.3 New policy measures

Structural reforms with regard to the German R&D and innovation system were continued in course of 2012, especially the '*Exzellenzinitiative*' (outlook: continue as before) and '*Pakt für Forschung und Innovation*' (outlook: further expanding).

High-Tech Strategy 2020

This strategy outlines the research and innovation policy of the federal government for the coming years. The main aims of the HTS are to create lead markets, intensify cooperation between science and industry, and to continue to improve the general conditions for innovation. With the proposed directions and instruments, basically all structural challenges can be addressed. On 28.03.2012, the federal government has adapted an Action Plan for the HTS-2020 and thus formulated 10 future-oriented projects (*Zukunftsprojekte*)[17] which aim at addressing the grand societal challenges. The federal government thus seeks to bundle the innovation relevant policies and initiatives of all federal resorts and also to bring together the efforts made at HEI/PRO and business sector, particularly in the fields of climate/energy, health/healthy food, mobility, communication, and security.

Draft for changing the German Basic Law (*Grundgesetz, Artikel* 91b)

This draft seeks to change the current regulation in terms of financing universities (in particular joint initiatives of federal and state level). As outlined in chapter 2.1 with regard to "national economic and political context" and again in chapter 3 below in the light of structural challenges the German system is facing, a main obstacle for significant changes in terms of Germany's education policy is the fact that it is subject to complex policy coordination since it is within the responsibility of the individual states. The initiative of changing the corresponding legislation is an attempt to improve the situation and allow for joint (federal and state level) permanent financing of universities (note: so far only temporary financing is possible). However, the initiative is still subject of a controversial political debate.

Freedom for Science law *"Wissenschaftsfreiheitsgesetz"*: The new law aims at making the budgetary rules of (publicly co-financed)[18] non-university research institutions more flexible, i.e. cutting red tape, providing more freedom on financial decisions and with regard to human resources management, etc.

Foreign Skills Approval/Recognition law *„Anerkennungsgesetz"*<more info> The new law came into force on 01/04/2012 and creates a legal entitlement to claim for recognition of foreign vocational education (to be decided within 3 months). The newly founded central institution IHK FOSA (Foreign Skills Approval) is carrying out the assessment and decides about recognition. <more info>

17 For the period 2012 – 2015, about €8.4b are earmarked for the mentioned *Zukunftsprojekte*. For further information concerning the individual projects see BMBF <link>

18 For instance, *Max-Planck-Gesellschaft* (MPI), *Fraunhofer-Gesellschaft* FhG), *Helmholtz-Zentren, Leibniz-Einrichtungen*, and *Deutsche Forschungsgemeinschaft* (DFG).

Beyond these new measures, in course of 2012, a significant number of programmes, thematic initiatives, and new/revised support schemes have been launched/extended (thus mostly converting R&D policy goals and thematic priorities as set out before into praxis). See below for some examples (not exhaustive!):[19]

- **NanoCare:** Support initiative assessing the impact of nano-materials on humans and environment (launched 26.11.2012).[20]
- **Formation of Berlin Institute for Health Research:** Cooperation of Charité and Max-Delbrück-Centre for Molecular Medicine **<**more info>
- **Formation of Consortia for Translationale Cancer Research: DKKT** (*Deutsches Konsortium für Translationale Krebsforschung*) <*more info*>
- *New Research Programme on* ***rare-earth materials*** (*Wirtschaftsstrategische Rohstoffe für den Hightech-Standort Deutschland*) which seeks to to support technologies which make more efficient use of the corresponding materials[21] and/or help to recycle them more effectively. For this programme, €200 million budget is earmarked by the BMBF.[22] <more info>
- Programme **"Zwanzig20 – Partnership for Innovation"**. By means of this programme the federal government (BMBF) aims at supporting cooperation in research. Over the period 2012 – 2019, a total budget of up to €500 million is foreseen. <more info>
- Two joint initiatives of BMWi, BMBF, and BMU concerning research on (1) **future-compliant electricity grids** ("*Zukunftsfähige Stromnetze*"; €150 millions from 2013 on) <link> and (2) **energy storage** ("*Energiespeicher*"), 60 new research projects are due to be funded. For examples see this <link>
- Research framework programme on **Civil Safety** (*Forschung für die zivile Sicherheit*). The programme forms part of the HTS-2020 and aims at improvements in the safety of citizens and crucial infrastructures. The earmarked budget is €55 million annually for the years 2012 – 2017.

2.4 Recent policy documents

With regard to Germany's research and innovation system, the most relevant policy document recently released is the report of the federal government concerning the future-oriented projects of the HTS-2020 (*Bericht der Bundesregierung: Zukunftsprojekte der Hightech-Strategie.* For the period 2012–2015, about €8.4b are earmarked for the mentioned projects (HTS-Action Plan: <link>).[23]

Furthermore, several studies have been conducted in course of 2012 identifying and analysing strengths and weaknesses of Germany's education system and in this light pointing towards policy recommendations. For instance, "Education in Germany" *Bildung in Deutschland 2012: 4. Bildungsbericht* (<link>) and the *Berufsbildungsbericht 2012* (<link>) assessing the situation of vocational training in Germany.

Finally, the Ministry of economic affairs and technology (*Bundesministerium für Wirtschaft und Technologie,* BMWi) released in 05/2012 a new strategy paper outlining a new / revised innovation

19 Source: BMBF press releases, Activities of the Ministry (until 28/11/2012).

20 For further info on the initiative see http://www.bmbf.de/de/nanotechnologie.php and http://www.nanopartikel.info. For the conditions of the support measures check this <link>.

21 Rare-earths, for instance, Indium, Gallium metals of the Platinum group.

22 By means of this programme, the BMBF seeks to contribute to the German *Rohstoffstrategie* and the *Ressourceneffizienzprogramm* as well as the joint initiative of BMBF and BMU "Green Economy".

23 For further information concerning the individual projects see BMBF <link.

concept meant to be the basis and providing a framework for future innovation-policy making. See: BMWi (2012): *Lust auf Technik – Neues wagen, Wachstum stärken, Zukunft gestalten* <link>.

2.5 Research and innovation system changes

Germany's research and innovation system is set up to adapt to a changing environment and to allow for continuous improvement with respect to its functioning. However, within the short time interval of one year (i.e. compared to the Country Report 2011), changes in the entire system are difficult to pin down. In fact, the group of main actors and institutions constituting the German research system did not change significantly in recent years. However significant efforts have been made to increase interconnections between relevant actors.

The federal government and the 16 state (*Länder*) governments share the political responsibility for research policy and funding (see Figure 1, above). At the federal level, the Federal Ministry of Education and Research (BMBF) has the main responsibility for research policy. The Federal Ministry of Economics and Technology (BMWi) is responsible for innovation and technology policy as well as for some areas of R&D policy. It provides, for instance, SME-oriented indirect measures, mission-oriented programmes in the area of energy research, aerospace and transport research, and deals with issues regarding an innovation-friendly environment. In addition, several other ministries maintain their own research institutes (*Ressortforschungseinrichtungen*). At the state level, responsibility for science policy is usually shared between the science and education ministry and the economics ministry. The Joint Science Conference (GWK) is the main body that coordinates research policies between the federal government and state governments.

In contrast to a number of other countries (e.g. Finland), Germany does not have a strategic policy council coordinating research and/or innovation policies and funding. The German Council of Science and Humanities (*Wissenschaftsrat* – WR), a joint institution with representatives from academia as well as from federal and state governments, performs some aspects of the work inherent to a strategic unit for research policy. Its main function is to evaluate and advise on the development of science, research and higher education.

The main task of the DFG is to select the best research projects on a competitive basis and to finance these projects, commonly based on a response mode to bottom-up application. Most publicly funded R&D programmes are administered and managed by a range of implementation agencies (*Projektträger*), which are mostly located in large research centres. In addition, the German Federation of Industrial Research Associations "Otto von Guericke" (AiF)[24] deals with the promotion of applied R&D for the benefit of SMEs. As said above, in course of 2012, no substantial changes of this system have emerged.

2.6 Regional and/or National Research and Innovation Strategies on Smart Specialisation (RIS3)

In Germany, the R&D and innovation relevant policy mix appears to be fairly developed both at federal and regional level (see chapter 4.3). However, it could still be improved. In fact, developing smart specialisation strategies could help addressing some shortcomings. Thus, the general understanding of what is a Smart Specialisation [iS3] evolved over the recent years from focussing on specialisation rather top down towards a diversification driven bottom up approach.

24 Since its foundation in 1954, about 180,000 research projects have been facilitated (which overall represent an R&D spending of €8.5b). AiF estimates that about 50,000 mainly midsize enterprises benefit from its support. See www.aif.de

Research and Innovation Strategies on Smart Specialisation (RIS3), from a conceptual point of view, may emerge in three forms: fully at national level (examples are territorially small Member States such as Malta, Cyprus, Baltic States, etc.), only regionally (i.e. no nationwide strategy, but explicit iS3 concepts at regional level), and as combination of the two (i.e. national overarching strategy complemented with further individual regional strategies (as for instance in Spain).

In Germany, for the time being, conceptualising explicit smart specialisation strategies appears to be done at regional level only.[25] This is likely due to the size and the federative nature of the country and the diversified responsibilities in terms of R&D and innovation activities between federal and regional level. However, it can be observed that not all German regions have undertaken explicit efforts in terms of elaborating an own RIS3. By December 2012, only few regions (Brandenburg, Saxony, and Saxony-Anhalt) had registered to the Smart Specialisation Platform of the EU and thus demonstrated search for competent support in this regard. Brandenburg and Berlin have developed a joint innovation strategy for the German Capital Region (innoBB; <link>), adopted in 06/2011. This joint innovation strategy outlines how Germany's capital region plans to further develop as an internationally competitive innovation zone. It is the result of a successful cooperation of all innovation policy players of both states, initiated in 2007. The strategy plans for even closer cross-border coordination, in order to concentrate forces and to enable the locations to position them optimally with regard to the global competition. To strengthen its position in the international innovation landscape and in order to more keenly shape the location's profile, innoBB is concentrating on the targeted setting up and developing of clusters with high development potential, in particular, energy technology, life sciences and healthcare, ICT, media and the creative industries, photonics and mobility.

Surprisingly, regions leading in terms of innovation performance, such as e.g. Baden Wuerttemberg, have not yet developed / communicated explicit 'smart specialisation strategies'. However, this does not mean that the innovation strategy applied in these regions is not 'smart' (i.e. it complies with the criteria set out in the "guide to Smart Specialisation" <link>). In fact, it is rather true that the leading regions in Germany (see ranking in Regional Innovation Scoreboard)[26] have been applying iS3 principles (although not labelled as such) already for many years and are often taken as case study examples when outlining successful RIS3 to regions seeking to catch up.

At federal level, according to a new 'Innovation Strategy' recently released by the BMWi[27], a number of initiatives are set up or planned which aim at providing a support to smart specialisation by strengthening business driven innovation clusters and enabling them to emerge as excellence centres recognised at regional and European level. However, there is no evidence of efforts at federal level pointing towards an overarching national RIS3 on smart specialisation for Germany (like in other EU countries, as for instance Spain.

At State level, the amount of efforts undertaken in elaborating RIS3 on Smart Specialisation seems to be quite different. This might be due to the fact that some regions rely/depend more than others on receiving money from the EU structural and regional cohesion fund. In this light it needs to be mentioned that the EU Cohesion Policy for 2014–2020 strongly focuses on re-

25 For efforts concerning raising awareness concerning iS3 and training of policy makers (i.e. workshops / seminars / trainings) see e.g. <link, link, link>.

26 For a comparative overview of regional research systems across Europe see e.g. Regional Innovation Scoreboard – 2012 and European Commission: Europe's regional research systems - current trends and structures, 2009 <link>. For regional innovation policy strategies check e.g. OECD (2009) <link, link> and for exploring regional structural and S&T specialisation across EU regions see EC (2009): <link>.

27 BMWi (2012)– *Bundesministerium für Wirtschaft und Technologie* (2012): Lust auf Technik – Neues wagen, Wachstum stärken, Zukunft gestalten <link>

search and innovation as a driving force for keeping the EU competitive and that therefore Smart Specialisation was chosen as ex-ante conditionality for granting support. Elaborating a comprehensive RIS3 on Smart Specialisation has thus a central function within the new programming period: each region which seeks to receive funds from this budget is obliged to design national or regional RIS3 for Smart Specialisation that highlight its innovative potentials. For the purpose of improving the quality of Operational Programmes, ex-ante evaluations prior to starting the implementation need to be undertaken. Arguably, the incentives to push for this differ across German regions since the mentioned ex-ante conditionality obviously is more/only relevant for regions which expect to receive funds from this budget, i.e. mainly the Eastern German regions. In this light it is surprising to see that Mecklenburg-Vorpommern and Thuringia (both are Eastern German regions) have not yet registered to the Smart Specialisation Platform, i.e. are not seeking support from the EC side in elaborating their RIS3 on Smart Specialisation. However, as potential recipient of support from the EU structural funds, the mentioned regions should be assumed to have a rather high interest in avoiding any delay in elaborating their strategies and performing the required ex-ante impact assessment (as this may put receiving financial resources from the EU at risk). Given the deadline set out by the EU for applying the ex-ante conditionality (2014), more efforts by German *Länder* with regard to developing own RIS3 on Smart Specialisation might be seen in course of 2013.

Moreover, as outlined above, the general question arises whether Germany may need an overarching national research and innovation strategy on Smart Specialisation in order to provide a frame and to some extent coordinating regional efforts in terms of iS3 or whether it can be left to the regions alone to elaborate their individual strategies (diversifying rather than specialising). Given the importance of R&D and innovation performance for Germany as a whole and also the disparities with regard to latter among German regions, at national and regional level a comprehensive dialog concerning "smart strategies" should be ensured. In this context, it could indeed be helpful having an overall vision at national level and a common approach towards developing RIS3 without narrowing the scope of Smart Specialisation strategies at regional level. Spain could be seen as a conceptual example in this regard: a national RIS3 is embedding individual regional strategies, thus not breaching extensive autonomies at the regional level.

Another example with regard to cross-region / even cross-border cooperation can be seen in the Danube Region Strategy which aims at better coordination and cooperation between the countries and regions across the Danube macro-region.[28] In fact, RIS3 as a regional policy concept carries a high potential for this and possibly also some other macro-regions as – by addressing challenges such as uneven socio-economic developments and fragmented innovation systems – it offers a clear path not only to more innovation and growth but also towards targeted cross-border, transnational and interregional cooperation for more critical potential.

2.7 Evaluations, consultations

The most comprehensive evaluation of the German R&D and innovation system is provided by EFI (Expert Commission on Research and Innovation) in its annual reports on Research, Innovating and Technological Performance in Germany (available in <DE>, <ENG>). The most recent report was released in spring 2012 (it is thus mainly relying on information from 2009 and 2010) and has been widely reflected in this Country Report. An updated EFI report should be released in February 2013.

28 The Danube region covers parts of 8 EU countries (Germany, Austria, Hungary, Czech Republic, Slovak Republic, Slovenia, Bulgaria and Romania) and 6 non-EU countries (Croatia, Serbia, Bosnia and Herzegovina, Montenegro, Ukraine and Moldova).

Moreover, the EFI commissions a number of research studies and evaluations of particular aspects of the German research and innovation system.[29] Furthermore, the BMBF has commissioned and released a study on the level of education in Germany (<link>).[30] However, some results are subject of a controversial discussion. See in this regard a related OECD document: "*Bildung auf einen Blick 2012*" <link>. The German Council of Science and Humanities (*Wissenschaftsrat*), which provides advice to both federal and state governments, releases periodically recommendations concerning the German research and education system (and studies dedicated to more specific aspects). These recommendations commonly rely on comprehensive considerations of system relevant aspects of the research and innovation landscape and might be therefore seen as the results of throughout evaluations <link>.

Finally, there are studies conducted by 'external' reviewers which analyse the German R&D and innovation policy making and corresponding programmes. [31] The following programmes have been evaluated recently: "SME Innovative"[32], "Research Bonus"[33], "industrial collective research" (IGF)[34], "Central Innovation Programme" (ZIM)[35], "EXIST"[36], "High-tech Start-up Fund"[37], and "SIGNO"[38]. Other programmes and initiatives are in the process of evaluation or foreseen to be analysed, for instance, "Spitzencluster-Wettbewerb"(Leading-Edge Cluster Competition)"[39] "ERP Start-up Fund", "ERP Innovation Programme", and "Validation of Innovative Potentials of Scientific Research". The "Initiative for Excellence" and the "Pact for Research and Innovation" are regularly monitored.[40]

In Germany, R&D support programmes typically run for a specified time period with the option of prolonging. Evaluations thus contribute to the decision whether to extend and/or to redesign policy measures. Overall, the results of evaluations of research and innovation policy programmes are positive about the efficiency and effectiveness of the analysed measures. The main findings of the evaluations might be summarized as follows: German research and innovation policy seems to be able to deliver support measures in an efficient and user-friendly way, i.e. addressing the specific needs of the target groups of the programme.[41] Policy programmes are generally evidence-based and designed along identified challenges and needs for public intervention.

29 For instance: the Studies No. 01/2012 on education and qualification in Germany and its role for competitiveness, No. 04/2012 on R&D activities in the German business sector, No. 06/2012 on Innovation behaviour of German companies in 2010, No. 09/2012: Performance and Structures of the German Science System in 2011, No. 16/2012 on research at German Universities, No. 15/2012 on effectiveness and additionality of public support to R&D. <link>.

30 For further information, statistics and evaluation of other aspects see BMBF data portal.

31 Note: Within the OECD Report Series Regions and Innovation Policy, there are no recent publications specifically dealing with Germany and according to the tentative planning there are no forthcoming publications in the nearer future.

32 Rammer, C., et al. (2012): Begleit- und Wirkungsforschung zur Hightech-Strategie: Systemevaluierung KMU-innovativ, Abschlussbericht, BMBF, Mannheim / Berlin. <link>.

33 Astor, M., U. Glöckner, D. Riesenberg, E. Schindler (2010).

34 RWI and WSF (2010): Erweiterte Erfolgskontrolle beim Programm zur Förderung der IGF im Zeitraum 2005 bis 2009, Essen: RWI.

35 Kulicke, M., et al. (2010): Evaluierung des Programmstarts und der Durchführung des "Zentralen Innovationsprogramms Mittelstand (ZIM)".

36 Egeln, J., et al. (2010): Evaluation des Existenzgründungsprogramms EXIST III.

37 Geyer, A., T. Heimer, L. Hölscher, C. Schalast (2010).

38 Astor, M., U. Glöckner, D. Riesenberg, C. Czychowski (2010).

39 Continuously evaluated by a consortium led by RWI, see <link>.

40 The "Initiative for Excellence" is monitored by the *Institut für Forschungsinformation & Qualitätssicherung* and the "Pact for Research & Innovation" by the Joint Science Conference (GWK).

41 PRO INNO Europe (2011a).

Recommendations of evaluations constantly focus on adjusting smaller programme details while being in favour of continuing the programme as such.

3 Structural challenges facing the national system

As outlined above in chapter I and II, the German national research and innovation system (RIS) is compared to other EU-27 countries comparably well developed. According to the Innovation Union Scoreboard 2011 (IUS-2011), Germany ranks third after Sweden and Denmark, i.e. lately Germany even climbed one position compared to the IUS-2010 and overtook Finland. However, all four mentioned countries are classified as "innovation leaders" within the EU-27 (see PRO INNO Europe, 2012). Within this group, Germany exhibits about the same average growth rate in terms of innovation performance as Finland and outpaces in this regard Sweden and Denmark; i.e. Germany appears to be further catching up with the top performers. Yet, the innovation performance of all other country groups (as defined according to the IUS-2011), in average, is rising even faster which points to an overall convergence in terms of innovation performance among EU countries in the mid/long term.[42] The assessment of Germany's innovation performance and the general positioning of the country within Europe, as provided by IUS-2011, are both widely confirmed by another comparative study investigating the innovation performance of 26 industrialized countries (Deutsche Telekom Stiftung, 2011); Germany is thus ranked fourth based on a composite 'Innovation Indicator-2011'. See below Table 2 for an ad hoc selection of further indicators characterising the German national RIS.

Notwithstanding, the German research and innovation system also shows some weaknesses and faces challenges which need to be addressed to further increase the innovation performance and to strengthen Germany's position.[43] This is especially critical since the German economy – due to its strong export-orientation – witnesses growing competition from emerging economies, in particular from China. No doubt, the international rivalry for technologies and market leadership will further intensify. The federal government has acknowledged this general challenge in the High-Tech Strategy 2020 (adopted in 2010, see discussion above).

In fact, innovation policy in Germany in the recent years had to respond to a number of challenges, some of which have been there for some time while others newly emerged.[44] For instance, an important barrier for the German business sector to increase investments in research and innovation activities continues to be the lack of appropriate financing sources. In particular, SMEs and high-tech start-ups face difficulties regarding financing R&D and innovation projects. The economic and financial crisis has reinforced this situation: Internal financing sources have decreased due to lower sales and, with respect to external financing, banks have become even

42 Evidence of overall convergence was found only between country groups; i.e. 'Moderate' and 'Modest innovators' clearly catch-up to the 'Innovation leaders' and 'Innovation followers'. Moreover, there was also evidence of convergence within the country groups (with the exception of MS classified as 'Moderate innovators'). See IUS-2011, Box-1 for further details.

43 On 7 June 2011, the European Commission published analyses of Member States' Europe 2020 National Reform Programmes (see IP/11/685 and MEMO/11/382), and proposed to the Council 27 sets of country-specific recommendations – plus one for the euro area as a whole – to help Member States gear up their economic and social policies to deliver on growth, jobs and public finances. The analysis in the report underpins those draft recommendations in so far as research and innovation issues are concerned.

44 See in this regard, for instance, the corresponding recommendations continuously been made by the national research council 'Wissenschaftsrat' (WR) <link>) and the ProInno-Europe: Mini-Country Report Germany 2011 <link>.

more cautious to finance innovation activities due to the risky nature and typically little collateral (a problem faced in many countries).[45]

Table 2: Selected indicators characterising the German national RIS
(Figures according to Innovation Union Scoreboard 2011, IUS-2011)

HUMAN RESOURCES	Absolute	Annual average growth [%]	IUS-2011 indicator value relative to the EU-27 (EU27=100)
New doctorate graduates (ISCED 6) per 1000 population aged 25-34	2.6	0.0	173
Percentage population aged 25-64 with completed tertiary education	29.8	3.6	89
Open, excellent and attractive research systems			
International scientific co-publications per million population	668	5.9	222
Scientific publications among the top 10% most cited publications worldwide as % of total scientific publications of the country	11.41	1.8	106
Finance and support			
R&D expenditure in the public sector as % of GDP	0.92	4.9	121
Firm activities			
R&D expenditure in the business sector as % of GDP	1.90	1.6	154
Linkages & entrepreneurship			
Public-private co-publications per million population	49.5	1.4	137
Intellectual assets			
PCT patents applications per billion GDP (in PPS€)	7.04	-1.1	186
PCT patents applications in societal challenges per billion GDP (in PPS€) (climate change mitigation; health)	1.00	0.6	156
Outputs			
Economic effects			
Medium and high-tech product exports as % total product exports	63.18	-0.9	131
Knowledge-intensive services exports as % total service exports	57.63	1.9	120
License and patent revenues from abroad as % of GDP	0.44	7.0	86

Note: Data refer to information as provided by the IUS-2011 (released Feb 2012, pp. 29ff and pp. 62ff <link>) and thus refer to Germany's 'current performance'. However, please note that the most recent data in this regard correspond to year 2010. Data can be retrieved from the PRO-INNO-Europe (Innometrics) website <link>. For an overview about the corresponding data sources see IUS-2011, pp. 10-11.

Although public support to R&D and innovation is recognised to be particularly crucial for SMEs, in general, it is relatively small in Germany compared to other countries although the federal government significantly increased already the budget of its main research and innovation financing programmes – ZIM, thematic R&D programmes, ERP Innovation Programme) – in 2009 and 2010 (the programmes provide direct support as well as facilitate access to finance). R&D spending of the German enterprise sector remained fairly stable during 2009 despite a 5% decrease in GDP (and an up to 30% fall of sales in R&D-intensive sectors), followed by a remarkable increase in 2010 and 2011 (see Table 1, above). However, this does not mean that there is no room for further improvement. According to the IUS 2011, the general level of 'finance and support' for R&D and innovation in Germany, compared to other innovation leaders in Europe, is critical. In this regard, Germany takes only position eight among the EU-27 countries. The normalized volume of public support to business sector R&D and innovation in Germany remains below the figures of other leading EU countries and the availability of Venture Capital (VC) for German firms is even remarkably below the EU-27 average. A national expert commission resumed in this regard that young high-tech firms still face a shortage of equity capital (EFI, 2011). Hence, the challenge for the German government remains to facilitate substantially the **access to finance for corporate R&D and innovation**.

Another important factor for the long-term development of an innovation system is the **supply of human capital**. Also in this regard Germany exhibits some weaknesses. In the light of several comparative OECD studies, areas of concern relate to detected deficits in secondary school ed-

45 For a comprehensive discussion of corporate R&D and innovation activities in times of a crisis see, for instance, Cincera et al. (2012).

ucation[46] resulting in shares of students with low scores in certain competences (i.e. just about OECD-average-level as tested in PISA 2009).[47] Furthermore, although the percentage of youth aged 20-24 having attained at least upper secondary level education (69.7%) is above the EU27 average (64.8%), Germany is not taking a top position in this regard in an international comparison. Moreover, there is still a comparably low share of population with a completed tertiary education (though the rate significantly increased during the last decade).[48] Further raise of concerns is given by the fact that there will be a generally decreasing number of young people graduating from secondary schools due to demographic change and also since only a comparably low share of tertiary students are actually graduating in engineering and natural sciences.[49] Finally, although immigration for high-skilled personnel lately has become somewhat easier, immigration barriers remain relatively high.

Overall, compared to Finland, Sweden, and Denmark – the peers with respect to leading innovation performance in the EU-27 – Germany ranks far behind in terms of education and human resources; according to corresponding IUS-2011 indicators, Germany ranks even below the EU-27 average. Admittedly, this is to some extent compensated by the dual system of vocational training in Germany which is well established and contributes significantly to the provision of qualified personnel for the labour market. However, the sufficient supply of a qualified workforce has been a constant challenge for many years. Although there are discussions about the extent to which a lack of qualified personnel is a bottleneck for the German economy, there is consensus that a shortage is present in individual occupations/regions and that the shortage is likely to grow in the future due to demographic changes (EFI, 2012). Accordingly, substantial efforts are needed to adjust the existing education system and the policy in a way allowing Germany to catch up with the European and world wide innovation leaders' performance in terms of **societal education level and availability of adequately skilled workforce**.[50] In response to this challenge, some reforms in primary and secondary education and major reforms in tertiary education (e.g. introduction of bachelor and master studies, introduction/abolition of fee systems for universities) are taking place. However, a main obstacle for significant changes in terms of Germany's education policy is the fact that it is subject to complex policy coordination since it is within the responsibility of the individual states. In fact, the federal government has only few competences and any changes in this regard would require changing the responsibilities as stipulated in the constitution (*Grundgesetz*). Moreover, adjustments in the education policy – once achieved (at primary, secondary as well as tertiary level) – take a long time until they have an effect. Accordingly, the outlined challenges with regard to education level and shortage of qualified labour likely will remain for many years to come.

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46 Note that there is no OECD study on primary school students. In this regard, the IEA-Studies TIMSS and PIRLS (both 2011) show that German primary students perform better than EU average and that the share of 'low performers' is comparably small.

47 In general, the shares of low performers in the OECD PISA Studies have become considerably smaller over the PISA cycle and are now (2009) lower than OECD-average in 'Mathematics and Science', and on OECD average level in 'Reading'.

48 The share of 30-34 years old having completed tertiary or equivalent education (ISCED 4), which is the corresponding EU-benchmark, Germany has just achieved the goal set out (42%).

49 In general, recent figures suggest that Germany is improving in most of these points but remains still behind its peers. See BMBF (2012): *Bildung und Forschung in Zahlen* 2012.

50 As a way forward in this regard, Germany could mobilise existing resources to a larger extent. Potentials lie in a greater participation of women, in particular in MINT-fields comprising mathematics, information technology, natural sciences and technology. In fact, compared to other industrialised economies, the share of women in research activities in Germany is relatively low, in particular in the business sector (OECD, 2011). Moreover, the 'social selectivity' in terms of higher education (social bias) needs to be reduced and further efforts could be made to use the potential of immigrants already living in Germany and to further attract qualified labour from abroad (EFI, 2011; Deutsche Telekom Stiftung, 2011).

A third main challenge for Germany arises from increasing international competition, particularly in knowledge-intensive sectors. Admittedly, Germany may appear well prepared for this as the innovation system seems to be well established and its R&D intensity (GERD/GDP) amounted to 2.84 percent in 2011, which is compared internationally at a fairly high level. However, first of all, this is only an interim result on the way to the three-percent target (in 2011: target missed by €4.15b spending on R&D). Yet, other countries have long exceeded the three-percent target. For instance, approximated by R&D intensity or according to the indicators of the Innovation Union Competitiveness Report – 2011 (EC, 2012), Germany remains – although well above the EU-27 average – remarkably below the figures of its peer-group in Europe (Sweden, Finland and Denmark) and is also lacking behind its main global competitors (Japan, Korea, etc). Moreover, emerging countries such as China are catching up rapidly and may challenge Germany soon.[51] In other words: Germany should orient itself towards the R&D intensity of the global leaders and not focus on the three-percent target or on any figure surpassed already (as e.g. the EU or OECD average in this regard). Keeping three-percent target as vision for R&D policy making – at least what concerns Germany – seems to be lacking ambition.

No doubt, on a global scale, Germany can only reach or maintain a competitive edge if the German innovation system continually generates new knowledge and flexibly adopts fresh impetus while transforming it into innovations on the market. Concerns in this regard arise from the fact that the German industrial innovation system is currently characterized by a (rather static) specialisation on medium-high-tech manufacturing, such as automotive, mechanical engineering, and chemicals. The growth potential in these areas, however, is regarded as limited in the future. In contrast, potential for high growth rates is seen in the high-tech sector which is underdeveloped in Germany (EFI, 2010). Thus, **enabling the high-tech sector** is important to realise further growth. This is also critical in order to keep pace with globally shifting technological frontiers and to adapt early to new technologies.

Some impetus in this regard may result from the new energy policy strategy in Germany (agreed on in 2011, in the light of the meltdown at the Japanese nuclear power plant of Fukushima). Accordingly, electricity production by nuclear power will be stopped by 2022. Hence, there is need for R&D and innovation in energy supply to compensate the nuclear phase-out. Within the next ten years, investment in renewable electricity production is expected to be expanded substantially. Yet, a key challenge is arising from the question how to manage the uneven quantities of electricity produced by renewables such as wind and solar technologies with the rather stable demand for electricity or how to balance regional differences between electricity production based on renewables in the North and high electricity demand in the South (which so far was supplied to a great extent by nuclear power plants). Current policy initiatives both in research and energy policy try to address these challenges by researching into new technologies for energy transmission.[52] Expanding the high-tech sector could contribute to cope with this challenge.[53]

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51 Emerging economies not only challenge Germany. In fact, they also provide plenty of opportunities for an export-oriented, highly internationalised and innovative economy such as Germany. This is particularly true for manufacturer of equipment and vehicles. Therefore, the German federal government is actively supporting increasing linkages between the emerging economies and Germany both in science and industry.

52 See for instance the 6. 'Energy Research Programme' (*Energieforschungsprogramm*, released 2011). Accordingly, €3.5b are earmarked to support R&D on energy related aspects for the period 2011-2014 (which represents a substantial increase compared to its previous period). For more info see <link>.

53 Related to this change in energy policy, E-mobility is another priority of the federal government's strategy in terms of energy innovation. E-mobility is thus regarded as a critical trend in automotive mobility. A national E-mobility initiative was launched (implemented measures so far: increased R&D efforts in the area of batteries, e.g. Innovation Alliance on Lithium-Ion batteries, and related technologies as well as demand-side policies such as tax exceptions.

4 ASSESSMENT OF THE NATIONAL INNOVATION STRATEGY

4.1 National research and innovation priorities

The main priorities in Germany's R&D&I policy have been pursued over the last couple of years. The same holds for the set of policy instruments in place. In fact, R&D&I policy in Germany is persistent and straightforward. The key priorities of research and innovation policy continue to be: (i) keeping pace with global technology trends (envisage to be technological frontier setter), (ii) ensuring sufficient funds for public and private R&D and thus keeping research excellence at a top international level, (iii) maintaining and further improve the industry-science link (i.e. enabling knowledge flows at the public~private nexus), and (iv) strengthening the education sector (at all levels) in order to stimulate knowledge creation, capability building, absorptive capacities and ultimately a qualified workforce.

The stability of the German R&D&I policy is seen as a necessary prerequisite in order to give enterprises and research organisations planning reliability and to pursue long-term oriented goals. Nevertheless, shifts in priorities and individual policy initiatives have occurred. Mission-oriented approaches in technology policy are reemphasised by the definition of future-oriented projects as part of the HTS-2020' Action Plan. In fact, mission-oriented measures have been implemented in the German innovation policy from the beginning, however, they received less attention during the 1990s and 2000s. In the light of the global challenges, the need of a more forward-looking research and innovation policy emerged which should be set up to stimulate private and public actors to develop ways to meet these objectives. The general aim is to further intensify links between science and industry in order to reap the full potential of the German research and innovation system.

In this light, several new measures have been implemented over the last three years. For instance, the "Validation of Innovation Potentials of Scientific Research" aims at facilitating the transfer of scientific knowledge into commercial applications by offering grants to researchers at PROs and HEIs.[54] Another example is the "*Forschungscampus*" programme which provides funding for long-term oriented partnerships between universities, public research organisations and private companies. It aims at developing new technologies in areas with high technological complexity and significant potential for radical innovation (and thus follows a recommendation made by EFI - the German Expert Commission for research and innovation (EFI, 2009)). Two further instruments for establishing networks between industry and science in key technologies have been introduced already in 2008 and received meanwhile increasing attention: the "*Spitzencluster-Wettbewerb*" (Leading-Edge Cluster Competition) funds regional networks while the "Innovation Alliances" initiative provides public funding for large-scale, long-term projects that are assumed to be critical for developing break-through technologies.

The overwhelming importance of excellent public research and education has been emphasized by continuing and expanding the "Higher Education Pact", the "Initiative for Excellence", and the "Pact for Research and Innovation Furthermore, the federal and state governments agreed in 2008on the "Qualification Initiative", which addresses all areas of education from early-childhood education to lifelong learning, and in 2010 on the "Quality Pact for Teaching" to im-

54 The grants are provided to further investigate the commercialisation prospects of the given scientific findings.

prove the study conditions and teaching quality. €2b will be provided in the "Quality Pact for Teaching" between 2011 and 2020.

Moreover, by adapting the new "Freedom for Science" law (*Wissenschaftsfreiheitsgesetz*) the budgetary rules of (publicly co-financed) non-university research institutions[55] are made more flexible. The goal is strengthening the scientific landscape in Germany, for instance, by providing more freedom on financial decisions including human resources management. With regard to improving the skilled workforce in Germany, the new Foreign Skills Approval/Recognition law (A*nerkennungsgesetz)* aims at facilitating the immigration of qualified personnel.[56]

4.2 Evolution and analysis of the policy mix

Research and innovation policies are at the top of the federal government's policy agenda. This prominent position of this policy area was reinforced in July 2010 by a new white paper of the federal government, the High-Tech Strategy 2020. It is a comprehensive, coherent and long-term strategy for research and innovation. It uses a cross-departmental approach, involving several ministries and policy areas. The strategy defines the priorities in R&D&I policy with a particular focus on the solution of the grand challenges. The importance R&D and innovation policy has in Germany was underlined by the fact that the corresponding public funding was not cut during the financial crisis in 2008/2009; in contrast, the budget was steadily further increased until 2011 and evidence suggests that this trend was sustained in 2012 and is expected to continue in 2013 although the GDP growth is slowing down again

As outlined above, the research and innovation governance system in Germany is well developed and stable. The federal and the 16 state governments share the responsibility for R&D&I policies with a clear division of duties (as stipulated in the basic law). The federal government takes up a variety of activities in R&D&I policies and may be regarded as the main state actor in the German innovation system. The federal states' main pillar in terms of R&D&I policy is funding universities. In addition, they are involved in science-industry linkages schemes and innovation programmes. There are also several joint activities of the federal and state governments, e.g. joint institutional funding of research organisations.

Education policy - up to the tertiary level - is the sole competence of the 16 federal states. Thus, education systems differ by state and coordination of education policy is cumbersome. The separation of educational competencies between the federal and the state level does not necessarily follow arguments of optimal policy allocation. In particular, at HEI funding received from *Bund* (federal government) is limited to temporary, scientific and research projects. The banning of cooperation between the federal and the state level regarding permanent research funding of universities is being advocated. Various experts and politicians call for the abolishment of the ban but the responsible 16 state ministries of education and cultural affairs fear losses of competence. A 2/3 majority in the parliament as well as a majority in the chamber of regions (*Bundesrat*) would be needed to change the law (GG), which is – given the current political majorities – rather unrealistic to be achieved in the nearer future.

Innovation policy in Germany covers a broad scope of measures and activities. While the bulk of programmes focus on technological research, some measures go beyond. For example, the ob-

55 For instance, Max-Planck-Gesellschaft (MPI), Fraunhofer-Gesellschaft FhG), Helmholtz-Zentren, Leibniz-Einrichtungen and Deutsche Forschungsgemeinschaft (DFG).

56 The new law came into force on 01/04/2012 and creates a legal entitlement to claim for recognition of foreign vocational education (to be decided within 3 months). The newly founded central institution IHK FOSA (Foreign Skills Approval) is carrying out the assessment and decides about recognition. <more info>

jective of the programme "go-innovativ" (launched in 2010) is to improve innovation management in small firms. Furthermore, demand-side innovation policies are an integral part of the innovation policy mix in Germany, comprising legislation and standardisation as well as lead-market initiatives. Recently, the High-Tech Strategy 2020 has reinforced the role of demand-side policies by defining five demand areas which future technology development should target. Through the instrument of so-called future-oriented projects, the link between fostering technology-demand and developing technologies that are needed by future users is established and demand-side and supply-side policy approaches are aligned.[57]

German R&D&I policy offers a broad range of public funding measures to strengthen research and innovation activities in the business sector. Thematic R&D programmes are the main channel to provide financial means and comprise a large set of individual programmes and sub-programmes. They usually aim at achieving fairly specific goals in given technological fields. The majority of support measures address R&D performing firms and encourage public-private collaboration.

Programmes and measures are regularly re-designed and re-launched, usually in the light of comprehensive evaluations. Such evaluations of German innovation policy measures are commonly quite positive with regard to the effectiveness and efficiency of the analysed programmes.[58] Nevertheless, the lack of tax-based R&D incentives in Germany as a continuous impetus for businesses to invest in R&D is often perceived as a drawback. Consequently, its introduction is frequently suggested (EFI, 2008, 2009, 2010, 2011; Deutsche Telekom Stiftung 2011). However, an introduction implies significant fiscal costs.[59]

In the German research policy, primacy is given to the support of quality and excellence. The selection of proposals within thematic R&D programmes is generally based on peer-review, i.e. purely grounded on the scientific and technical quality of research concepts and the targeted level of innovativeness. The German Research Foundation (DFG) also supports excellence in academic research by offering grants for bottom-up research projects on a competitive basis according to scientific excellence and quality criteria based on peer review. Moreover, excellence in research is monitored by regular evaluations of public research organisations and university faculties.

In recent years, the focus on research excellence has been further emphasized in the context of the "Initiative for Excellence", a joint programme of the federal government and the *Länder,* which provides funding in a competitive way according to excellence criteria. In three funding lines (Graduate schools for the promotion of up-and-coming researchers; Excellence clusters for the promotion of cutting-edge research; institutional strategies to promote top-level university research), funding is granted on the basis of peer review in a two-phase procedure supervised by the German Research Association (DFG) and the German Council of Science and Humanities (WR). The final decision was taken on 15 June 2012 by the Approval Committee for the Initiative for Excellence (science: 39 votes, ministers: 32 votes)..

According to the European University Association (2009, 2011),[60] the autonomy of universities is rather limited in Germany. Increased flexibility in terms of budgets, which was implemented for PROs (*Wissenschaftsfreiheitsgesetz*), was not adopted for German universities. However, over recent years a change of paradigm occurred that involved movement from detailed input-oriented state

57 For more details and examples on the role of demand-side innovation policies see chapter 3 in the TrendChart Mini Country Report/Germany, 2011.

58 See PRO INNO Europe, 2011a.

59 Depending on the type of incentive, estimations for the costs vary between €460m and €5.7b (Elschner/Ernst/Spengel, 2011).

60 Note that Germany in 2011 has not been evaluated at aggregated country level rather than exemplary by looking at certain regions, namely North Rhine-Westphalia and Brandenburg.

control to an output-oriented form of global control. Currently, almost all *Länder* are working with flexible institutional budgets and with indicator-based allocations of funds. A new salary scheme for professors, based on performance criteria, has been introduced. In some *Länder*, contracts between state and universities –which describe the performances expected of the institutions –have been concluded.

As outlined above, Germany exhibits significant challenges in ensuring a throughout high level of education and the right mix in terms of appropriately skilled workforce. In fact, insufficient supply of qualified labour is a constant challenge. Various measures and initiatives are in place to strengthen the education system and to mobilise human resources. For example, the continuation of the "Higher Education Pact 2020" was decided in 2009 and further expanded in 2011 to create 327,000 additional places for university entrants (compared to 2005) expected between 2011 and 2015. The national 'Pact for Women in MINT Professions' was implemented to attract more women to courses in the so-called MINT subjects (including mathematics, information technology, natural sciences and technology). Some progress has been made but further efforts will be needed. One opportunity is to mobilise existing resources to a larger extent (women, foreign-born residents). Another is to stimulate immigration (see in this light the Foreign Skills Approval/Recognition law, approved in 04/2012).

Partnerships between research and innovation stakeholders are quite well developed in Germany. A broad range of links between science and industry are supported, such as cooperation, clusters, networks, alliances, and most recently public-private partnerships. In addition, the German science system includes a number of organisations that are devoted to knowledge transfer with the business sector, including the Fraunhofer Society (FhG), technical universities, and universities of applied science. Most of the universities have their own knowledge transfer office. Moreover, the funding programme "SIGNO" supports universities, companies and inventors to identify inventions suitable for patenting or other secure legal protection for intellectual property rights and to exploit them commercially. Nevertheless, external experts as well as government bodies still perceive an untapped potential to link research results to commercialisation and suggest expanding technology and knowledge transfer mechanisms (stimulate / improve effectiveness of public~private nexus).

Several initiatives are in place seeking to further improve the framework conditions for private investments. The importance of a constructive environment is inter alia acknowledged in the High-Tech Strategy 2020. Measures range from strengthening the start-up culture to facilitating access to venture capital. Some progress can be observed. However, given the comprehensive assessment of the German system provided by the IUS-2011, in comparison to the main peers (such as Finland, Sweden, etc.) and also to the EU-27 average, Germany has to improve access to finance for R&D and innovation significantly. This point is seen as one of the main threats to the German system. Opportunities for further improvements remain in particular for the provision of equity to companies. To facilitate access to public support, the BMBF established the "Federal Research and Innovation Funding Advisory Service" as the central point of contact for any questions concerning research and innovation funding. In general, relevant information about public support programmes are accessible through the internet. Applications can also be submitted online. However, the transparency about the broad range of existing support schemes needs to be improved. A first approach has been undertaken by bundling programmes, for instance, within the "Central Innovation Programme" (ZIM).

The use of public procurement as an instrument to stimulate innovation and R&D is gaining ground in Germany. In a joint statement, six federal ministries with responsibility for a high volume of orders decided to pay more attention to innovative solutions within public procurement. Furthermore, the Law against Restraints on Competition (GWB) was modified in 2009 in such a way that public authorities can also require innovative aspects apart from a social and an environmental dimension in the service specifications. Overall, procurement of innovative products has increased, in particular with respect to energy efficiency. But a binding strategy for innovation-oriented procurement is not yet in sight although public procurement as an instrument offers ample potential in this regard.

4.3 Assessment of the policy mix

The main challenges that Germany is confronted with in the area of research and innovation are the expansion of research in cutting-edge technologies, the provision of sufficient funding for R&D, the commercial exploitation of scientific knowledge, the provision of a qualified workforce, and responding to the new energy concept through 'green' energy (see above for more details). The current policy mix addresses these challenges through a broad range of measures.

The High-Tech Strategy 2020 outlines the research and innovation policy of the federal government for the coming years. The main aims of the HTS are to create lead markets, intensify cooperation between science and industry, and to continue to improve the general conditions for innovation. With the proposed directions and instruments, basically all structural challenges are addressed. However, making this strategy a success and achieving the goals set out requires a continuous monitoring and timely fine tuning of the instruments. Moreover, evaluations of the strategy as such will be needed too in order to ensure its appropriateness in a changing world; eventually an updating of vision and priorities might be needed before 2020.

The federal government is funding cutting-edge technologies with numerous initiatives and measures (see examples above), e.g. within thematic R&D programmes and by means of innovation alliances such as "*Spitzencluster*" (Leading-Edge Clusters). Current initiatives are embedded in the objective to create lead markets.[61] Lead markets are thus expected to help addressing the grand challenges. However, changing industrial structure is challenging and takes time. While evaluations of longer existing programmes are positive, the success of newly initiated measures and recently chosen approaches remain to be seen. Overall, the launched initiatives address a number of bottlenecks assumed to prevent the further emergence of the high-tech sector in Germany and accordingly appear promising. However, it remains doubtful whether the measures taken will be sufficient to make Germany catching up with the macro regions/countries leading in high-tech industries (US, Japan, Korea, etc.) within the time frame set out (2020). Note in this regard that a simulation of a series of growth scenarios for R&D intensive firms revealed that in year 2020, even under very optimistic assumptions, the gap to the US in terms of high-tech sector would remain to be significant. In other words: It would not be realistic to assume that by 2020 Germany could have closed the gap in terms of high-tech to the US (and other leading macro regions).[62]

As mentioned above, a constant challenge is finding external sources for financing R&D&I activities. This holds in particular for SMEs and young high-tech firms and was further reinforced by the financial crisis. Policy makers in Germany responded by offering funding instruments with an increased focus on SMEs (SME innovative, ZIM). As part of the second 'recovery pack-

61 The notion of lead markets was implemented as a new approach in the HTS-2020.

62 See: Voigt and Moncada (2012). The paper investigates how would sector composition and the magnitude of R&D investments in the EU differ in year 2020 compared to the past, if a selection of top R&D-investing SMEs were assumed to be on a fast growth track while the top R&D-investing large scale companies continued to grow as before. The study indicates that if one expects the (R&D-intensive) small firms to be a driving force for a substantial structural change in the EU economy, from being driven by rather medium-tech sectors towards a high-tech based economy, it requires either a significant longer time horizon of the assumed fast growth track than the simulated 10 years, or small firms' growth figures which even exceed the assumed 30% annually (as in the most optimistic scenario). In fact, neither case appears to be particularly realistic.

age', the budget of the ZIM programme was increased substantially in 2009 and 2010. As a response to the low share of early-stage VC investments, federal VC programmes were redesigned and expanded. For example, the second "High-tech Start-up fund" (*High-tech Gründerfonds* II) was introduced in October 2011 with an additional investment volume of €293,5m. Evaluations of the programmes are positive so that they contribute to mitigate the shortage of capital.[63] However, there is still room for further enhancements. As outlined above, according to the IUS-2011, Germany is still lacking behind and achieves only 53% of the EU-27 average in terms of VC. This is the lowest indicator in relative terms for Germany across all IUS dimensions. Evidently, framework conditions for the provision of equity for firms need to be improved. Among others, constraints in the legislation for foundations and endowments can be eliminated in order to use them as an additional source for funding private research and innovation (EFI, 2010; 2011).

Facilitating the knowledge exchange between science and industry enables and accelerates the commercial exploitation of research results generated by public institutions. Fostering science-industry links has been a policy priority in German research and innovation policy for many decades. A broad range of links are supported, including co-operations, clusters, networks, alliances, and most recently public-private partnerships. For example, the Expert Commission for Research and Innovation highlighted the "*Spitzencluster-Wettbewerb*" (Leading-Edge Cluster Competition) as a good way to promote promising innovation clusters (EFI, 2010). The programme provides funding for clusters, comprising firms, research organisations and government authorities that aim at jointly developing and introducing innovations in a certain field of technology or sector within a specific region. Cluster activities may involve skill development, long-term oriented research strategies, close-to-market technology development, facilitating new business ventures and international cooperation. Moreover, entrepreneurship at universities and technology transfer activities are supported. In order to further extend and improve science-industry links two new measures ("Validation of Innovation Potentials of Scientific Research" and "*Forschungscampus*") were recently introduced and complement existing instruments.

Finally, the education system in Germany has to respond to the challenges of the knowledge society, but exhibits obviously some weaknesses. In fact, meeting the economy's demand for high-skilled labour, in terms of both quantity and quality, is a constant challenge for the German education system. The government has recognized this challenge[64] and is trying to address it by means of a number of initiatives. First of all, the federal government has increased the overall investment in education. A number of new initiatives were set up, others were updated and expanded to strengthen the education system and to mobilise human resources, such as the "Higher Education Pact", the "Initiative for Excellence", the "Pact for Research and Innovation", and the "Quality Pact for Teaching". In 2008, the federal and state governments agreed on the "Qualification Initiative" for Germany which addresses all areas of education from early-childhood education to lifelong learning. Examples are the upgrading scholarships programme which allocates grants to people with good vocational qualifications to study at a HEI, support measures for lifelong learning, and the "National Pact for Women in MINT Professions" to attract more women to courses in the so-called MINT subjects. A scholarship programme for students (*Deutschlandstipendium*) provides grants since summer 2011. Furthermore, actions are taken to remove barriers for immigration of highly qualified and highly skilled persons (e.g. by means of the 'Foreign Skills Approval/Recognition law' (*Anerkennungsgesetz*). However, although progress is observed like growing enrolments of students at universities, further measures are necessary to improve the education system and to secure a sufficient supply of qualified workforce.

63 See Technopolis 2010 (evaluation f the *Gründerfonds* II, commissioned by BMBF <link>

64 During the first education summit in 2008, the federal government and the states called for an "Education Republic of Germany". The objective of an "Education Republic" was stressed again by the new coalition, formed in 2009. Mobilising skilled workers is also a stated objective in the High-Tech Strategy 2020.

Intensified efforts are needed in primary, secondary as well as higher education. According to OECD studies, Germany is lacking behind and not catching up (fast enough) compared to countries leading in terms of education performance (e.g. in Scandinavia). For example, greater efforts are needed to remove social barriers to education and to encourage young women to study mathematics, engineering and science. Corresponding family policy is also required, e.g. through the provision of sufficient childcare facilities and the establishment of a more family-friendly corporate culture.

Overall, changes in the education system need a long time until they become apparent in performance indicators. Furthermore, by virtue of the federal structure legislative powers for the school and higher education sector lies in the hands of state governments. Thus, legislation, administration and financing in these areas are almost exclusively a matter of the *Länder*. The federal government has almost no competences in education policy which appears to be a challenge for the German education system. For instance, by introducing more joint tasks into the framework of the federal structure, the federal government could contribute to a larger extent to education. As outlined above, there is currently a corresponding political discourse going on. However, for the necessary change in the constitution a broad consensus is needed and the required majority (in both chambers) is currently difficult to reach.

Finally, in order to compensate the recently decided nuclear phase-out until 2022 and to secure the energy supply afterwards (for a reasonable price), research and innovation activities in renewable electricity production need to be further expanded. The federal government supports this field since a long time. In 2007 it launched a comprehensive package of energy and climate policy measures: the “Integrated Energy and Climate Programme” (IEKP). Among others it contains a broad range of measures, especially aiming at increasing energy efficiency and advancing the use of renewable energy. Future-oriented projects are included in the HTS-2020 and the corresponding Action Plan, for example the project “Intelligent restructuring of the energy supply system”. Supporting instruments of various ministries are also in place to tackle the challenge. Their policies and activities are coordinated at the "Coordination Platform for Energy Research Policy" at the BMWi. Nevertheless, the objective is rather challenging and its achievement remains to be seen.

Overall, R&D&I policy in Germany responds to the key challenges that the German innovation system is facing. The HTS-2020 as well as the plenitude of implemented measures seems to be appropriate to mitigate the structural challenges (EFI, 2011; Deutsche Telekom Stiftung, 2011). However, the success of the HTS-2020 will critically depend on its further implementation process (EFI, 2011). The potential of only recently implemented measures have not been unfolded yet and remain to be seen. Moreover, further efforts and instruments are required, particularly in the education system, with regard to access to finance for corporate R&D and innovation activities (especially in SMEs and start-ups), and concerning the redefined energy policy.

Table 3: Assessment of the German policy mix

Challenges	Policy measures/actions addressing the challenge	Assessment in terms of appropriateness, efficiency and effectiveness

Challenges	Policy measures/actions addressing the challenge	Assessment in terms of appropriateness, efficiency and effectiveness
keeping pace with global technology trends	New approach: creation of lead markets to address societal challenges. Various measures are directed towards cutting-edge technologies (e.g. thematic R&D programmes, innovation alliances; embedded in the HTS-2020) as well at supporting new technological developments and its adaptation. Ultimate goal: Envisage to become technological frontier setter (thus ensure competitiveness and jobs in DE)	Changes in industrial structure are difficult to induce (by policy makers) and take time. The programmes in place appear to be tackling the right challenges and actions taken seem to be reasonable and widely appropriate. However, success of new approaches remains to be seen. Nevertheless, as known from technological history, cutting-edge technologies / break-through innovations often emerged from SMEs / start-ups. Since access to finance for R&D and innovation activities in Germany is generally limited and appears to be particularly difficult for small firms, the individual challenges are linked, i.e. they cannot be seen / tackled in isolation. In other words, whether or not Germany will manage to keep pace with global technological trends will – apart from the corresponding support measures – also depend on access to finance for small firms, supply of appropriately skilled workforce, knowledge capacities and quality of transfer systems, etc.
ensuring sufficient funds for public and private R&D and thus keeping research excellence and innovativeness at a top international level	High-Tech Strategy 2020 Initiative of Excellence Increased focus on SMEs in public R&D programmes (such as "SME innovative", "ZIM", etc.). Expansion of the provision of VC through "High-tech Start-up Fund II". Note: various (not all) programmes provide funds based on an assessment of excellence/peer reviewing	Evaluations of programmes are widely positive. However, overall volume of finance available for R&D still needs to be expanded. In this regard, framework conditions for the provision of equity could be improved further. Introduction of tax-based incentives for R&D may provide new impetus for business enterprise R&D expenditure. Actions taken seem to be reasonable and widely appropriate but insufficient in volume and leverage. Room for further advancements!
maintaining and further improving the industry-science link	Ultimate goal: Commercial exploitation of scientific results through enabling / intensifying knowledge flows at the public~private nexus (HTS-2020) Strong focus on industry-science links in R&D funding programmes; support of various forms of links including cooperation, clusters, networks, alliances, partnerships. Moreover, entrepreneurship at universities and technology transfer activities are supported. Examples: "Validation of Innovation Potentials of Scientific Research" supports investigation of market potential of public research results. "*Forschungscampus*" programme helps establishing public-private partnerships.	Knowledge transfer between industry and science is working relatively well and is supported already in various ways. However, it might be further improved in order to shorten the time needed to make a good idea becoming a commercially successful product, e.g. by cutting red tape, providing appropriate support to SMEs/start ups, improving incentives for researchers working in HEI/PRO to collaborate with businesses, facilitate spin-offs, etc. There is a broad range of existing and new programmes to further strengthen the industry-science link and to commercially exploit research results to a larger extent. Actions seem to be generally appropriate. However, commercial success / further rise in competitiveness and evidence of improvements in terms innovativeness in Germany still need to be seen.

Challenges	Policy measures/actions addressing the challenge	Assessment in terms of appropriateness, efficiency and effectiveness
strengthening education sector at all levels in order to stimulate knowledge creation, capability building, absorptive capacities	Ultimate goal: Ensuring supply of an adequately qualified workforce Several initiatives to strengthen education system and to mobilise human resources are in place, including "Higher Education Pact", "Qualification Initiative" Opening of the labour market for third country residents (Blue Card), recognition o foreign diploma/certificates High-Tech Strategy 2020	Initiatives have been successful as far as implemented and evaluated. However, there are still large untapped potentials (e.g. by further opening the labour market to skilled immigrants). Complex coordination in education policy owing to split competences prevents Germany's education from unfolding its full potential. Actions seem to be appropriate but room for further advancements, particularly regarding structural developments (reform of federalism in order to boost education sector).
Foster research and innovation in energy supply	High-Tech Strategy 2020 Broad range of support programmes by various ministries, e.g. the "Integrated Energy and Climate Programme" (IEKP) aimed at increasing energy efficiency and stimulating the adaptation of renewable energy technologies	The objective of nuclear phase-out until 2022 is rather challenging. Actions seem to be appropriate. However, whether they are sufficient in order to ensure that by 2022 economically priced solutions for the key technological questions can be found remains to be seen.

5 NATIONAL POLICY AND THE EUROPEAN PERSPECTIVE

With the European Council conclusions 04/02/2011, Member States are committed to completing the European Research Area (ERA) by 2014. The overall objective of the ERA Framework is to improve the coherence and compatibility of all MS and EU research policies, programmes and activities. Simultaneously diversity and competition are necessary counterbalances to more coherence and compatibility. They help to diversify and stabilize the research and innovation system in Europe on a competitive basis and to secure its excellence. The topics taken into account in developing the Framework include, for instance, quality of doctoral training, mobility of researchers, cross-border operation of research performing organisations, dissemination, use and transfer of research results, research infrastructures and consistency of international cooperation strategies and actions. Hence, any national and/or regional policies addressing such aspects always have a European perspective too.[65]

Germany is well embedded in the ERA and plays a crucial role for its functioning and its further development.[66] Stimulating in this regard was the rise in terms of private sector R&D intensity in Germany (from 1.73% in 2000 to 1.9%[p] in 2011) which was mainly due to the increasing importance of some key medium-high and high tech sectors, such as medical precision and optical instrument, motor vehicles or machinery equipment, in the overall economy. Overall, the current structure of the innovation system has been the basis for Germany's position as a leading innovator as indicated inter alia by the turnover generated by new products and as world leader in export of industrial goods. In particular, the strong role of the medium-high technology manufacturing sectors makes the German economy one of the most research oriented. However countries such as Sweden count on higher research intensity in business enterprises (proportion of private R&D investment over total value added in the same sector), which can endanger the long-term competitive edge of some sectors in Germany. The German High-Tech Strategy aims at responding to this challenge by encouraging a shift towards cutting-edge technology in the context of an overall objective of strengthening the innovation efforts of as many companies as possible regardless of sector or technology (IU Competitiveness Report 2011 - DE).

Looking from an EU perspective, while the variety of new instruments and approaches to exploit new forms of cooperation and coordination across Europe is – in principle – fit for purpose, there is a general danger of over-complexity. Many initiatives are not yet fully shaped and key approaches like the Innovation Partnerships and Joint Programming will necessitate a com-

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65 For a discussion of main challenges and suggestions concerning R&D&I policy at EU level see, for instance, European Research Area Board (ERAB) Reports. <link>

66 German partners are strongly involved in projects within European initiatives such as ERA-Nets, joint research programmes according to Article 185 of the Treaty of Lisbon, Joint Programming Initiatives, and Framework Programmes. At the same time, research programmes by the federal government and German Research Foundation (DFG) are further opening up to foreign entities and access to research infrastructures for the transnational scientific community is provided by opening large infrastructures located in Germany. Moreover, further steps are undertaken to remove formal constraints on researchers' mobility. However, looking e.g. at ERC participation statistics underlines that German host institutions are less attractive to international researchers. Federal and state governments jointly have to make sure that framework conditions for career, working and living such as contracting, payment, social security and similar offer flexibility to the needs of international researchers. Note in this regard that Several EU initiatives and instruments have been deployed with a view to addressing the issues that are crucial to enhancing researchers' careers and mobility. See e.g. European Commission (2011d): Sate of the Innovation Union 2011, p. 14ff for tasks/challenges. <link>

bination of existing approaches at national and European level, which will be challenging. Moreover, as commonly postulated by assessments of European instruments, application and funding provisions yield a highly bureaucratic effort and thus pose a systematic entry barrier.

By reflecting these and further European level developments, however, a comprehensive study of "Germany and the European Research Area" (EFI, No. 03/2011, <link>) arrived for the German research system to the following conclusions:

(1) Overall, the participation in European instruments results in net benefits for Germany (see <link>, p. 33). Moreover, financing R&D through structural funds is a big change and seems to work fine in Germany. Hence, Germany profits from introducing Lisbon priorities into structural funds.

(2) Perhaps the most important benefit for Germany remains the improved opportunity structure for national researchers as a catalyst for international collaboration. Participation is therefore not a hobby horse or simply a matter of "money back", but of important national interest. More particular, German participation and representation in most of the new instruments is leading in Europe (ERA-Nets, EIT, and partly for ERC and ETPs). For further details see <link>.

The EU level developments have moreover fundamental implications for national policy and policy-making. Before ERA, the policy of optimising participation in the framework programme, in order to secure a financial neutral return flow or even net benefit, could be regarded as sufficient. However, the ERA-developments and the process of internationalisation and Europeanisation of research and research funding require more: National governments need a strategy, i.e. clearly defined goals and an approach on how to achieve them, in particular the creation of win-win situations for national and European actors, the combination of national and European goals and approaches, the mobilization of adequate representation at European level, the coordination among national ministries and funding bodies and the mediation of interests articulated by stakeholders in particular within public research (in Germany mainly DFG, HEIs, PROs).

The authors of the mentioned study[67] further point out that – although there is no explicit strategy towards ERA – Germany has developed in the last years a strategic thinking and action towards the ERA. There is a strong involvement of national policy makers into the five ERA-Initiatives and other European issues, which is underlined as a clear improvement compared to earlier years. EU level instruments are being used for national goals, and there are attempts to influence the European level policy with core ideas as set out in the Internationalisation Strategy and High Tech-Strategy. Triggered by a broadening of R&D policy and innovation policy at EU level, there have been steps towards a more functional "horizontalisation" at national level, i.e. European involvement is becoming part of the strategic thinking and there is a stronger awareness of European issues across all ministries (e.g. visible in ERA-Net participations).

However, there remain several challenges when it comes to maximise the benefits of the ERA development for Germany and contribute to an optimised ERA development. Not all of them can be addressed by the German federal government, which however, can take a leading or at least supporting role.[68] Indeed, national governments need to join forces in a number of areas, such as, for instance, in order to face the centralising character ("magnetism") of Commission initiatives; to address the danger of an over-complex and unwieldy instrument landscape; to promote the internationalisation of the ERA; and finally to further pursue the simplification of application procedures. On the other hand, the increasing number of instruments, programmes

67 See Daimer, S.; Edler, J.; Howells, J. (2011).

68 According to the Expert Commission on Research & Innovation the federal government could intensify its role in the European coordination process and take a lead in the area of research and innovation in order to shape the ERA (EFI, 2011; re-emphasised in EFI, 2012).

and initiatives most notably on similar topics at EU and national level tends to lead to a continuously growing complexity, increased need for coordination, and soaring costs for all actors across EU. Measures need to be taken in order to avoid that this process will hamper more and more the engagement of researchers, research organisations, funding organisations and enterprises; in Germany and elsewhere. For instance, within the field of ageing currently exist the JPI (More Years, Better Lives), an art.185 initiative (Ambient Assisted Living), an EIP (Active and Healthy Ageing), and possibly soon a KIC (Innovation for healthy living and active ageing) to be launched by the EIT. The European Commission is therefore called to better explain the coherence of the ERA landscape and clarify the focus of the existing instruments and their interdependencies. Further issues, in turn, could be remedied most effectively at national level. In Germany, for instance, more specific analysis is needed in order to find out which groups have systematic disadvantages with respect to the application procedures.

Overall, the old times of clear division of what is European and what is national in research and innovation policy are gone for good. There is no alternative for German policy to the capturing of the opportunities that lie in a more coordinated European Research Area, especially as it turns into a Research and Innovation Area. The continuous challenge will be to work towards the right balance and synergies between national, internationally coordinated and supranational policies and instruments. To do so, policy makers, administrations and other stakeholders across Germany need to continue constructive dialogue and engagement as well as improve monitoring, analysis and reflection for decision making in an increasingly complex world. As outlined in the chapters above, the key challenges that Germany's national and regional R&D and innovation policies is currently confronted with are the following: expansion of cutting-edge technologies, provision of sufficient funding for R&D and innovation activities of SMEs and high-tech start-ups, further commercial exploitation of research results, provision of a qualified workforce, and responding to the new energy concept through 'green' energy. Mastering these challenges is crucial to secure and accelerate innovative dynamics in Germany. In other words: If these challenges are not successfully addressed they have the potential to create bottlenecks for the innovation system and to limit further economic growth.

In this light, the German federal government has moved all three areas research, innovation and education further to the core of its growth policy (BMBF, 2010) and is fully aware of the mentioned challenges. Public investment in these areas was increased in recent years and is scheduled to further increase. The priorities in R&D&I policy as outlined in the HTS-2020 as well as the current policy mix are set up to address the main challenges. Equivalent to the assessment presented in the ERAWATCH Country Report for Germany in 2011, no particular imbalance between the R&D&I policy actions and the challenges could be identified. The measures are well proven and are assessed to be relevant and appropriate to mitigate the structural challenges. However, whether the measures are sufficient to completely overcome the challenges, in particular the challenge regarding the financing of R&D in SMEs and start-ups and the new challenge due to the redefined energy policy, remains to be seen. Regarding education policy, especially structural developments such as the cooperation ban in education between the federal and the state governments have not yet been tackled (i.e. are still subject of a controversial political debate).

In a nutshell, Germany's R&D&I policy is rather stable and predictable due to multi-annual programmes. The steadiness in R&D&I policy in Germany – which was also maintained during the economic and financial crisis – appears very reasonable since the main challenges the German research and innovation policy has to deal with do not change significantly on an annual base. Moreover, continuity and long-term orientation of policy instruments is necessary because changes in structures and the behaviour of actors take time. Although the principal research and innovation policy instruments in place remain stable, they are regularly re-designed and adjusted in order to respond to changing framework conditions. Nevertheless, a number of new measures that complement the existing policy mix was initiated only recently (based on the new High-Tech Strategy). Their whole potential and effects have not been unfolded yet and remain to be seen. The overall success of the High-Tech Strategy will also critically depend on its further implementation process.

Policy offers a number of initiatives to strengthen research and innovation activities in the business sector. Most measures focus on excellence, both in terms of scientific excellence in public research and 'market excellence' in applied R&D performed by enterprises or through collaborative research involving firms and public research institutions. Consequently, the corporate R&D&I activities have to target new products and processes that are world novelties. Firms focusing their activities on adapting existing technologies and developing customer-specific products and more efficient internal processes tend to find it difficult to receive public funding for their R&D activities, particularly if they choose to do R&D without external project partners. For this large group of enterprises, which comprises most of R&D-performing SMEs, alternative funding instruments are required. Tax-based incentives for R&D are discussed in this regard as they may provide a continuous impetus to invest in research and innovation and could complement the current German policy mix for funding business R&D. However, introducing tax credits would imply significant fiscal costs.[69]

The increasing focus on promoting scientific excellence, particularly in the context of the "Initiative for Excellence" (*Exzellenzinitiative*), may change to some extent the incentive structure in science. A recent study for the Expert Commission for Research and Innovation (see Fraunhofer-ISI et al., 2012) shows that the current discourse on excellence and scientific competition at universities leads to increased activities in basic research and academic publication, but provides little impetus for strengthening knowledge transfer activities. However, focussing on excellence can also indirectly promote industry-science cooperation as industry often looks for the most outstanding researchers as cooperation partners (see Grimpe, 2010). Indeed, there is a significant number of collaborative activities involving industry within the projects funded through the "Initiative for Excellence" as well as through the "Pact for Research and Innovation" which provides additional funding for the four largest non-university public research organisations. As outlined above, special attention needs to be paid to education policy in Germany. The federal government as well as state governments have increased the investment in higher education (foremost through the "Higher Education Pact" and the "Quality Pact for Teaching"). In addition, various measures and initiatives are in place to strengthen the education system and mobilise human resources. Though progress has been made, greater efforts are needed in primary, secondary as well as in higher education,[70] for instance, in order to achieve more social equality concerning the access to education, to increase the participation rate in tertiary education, to encourage young men and women to study mathematics, engineering and science, and to use the potential of foreign-born residents. By allowing cooperation between the federal government and the state governments in the school and higher education sector, the federal government could contribute to a larger extent to education. As mentioned above, there is currently a controversial political debate revolving around introducing more joint tasks into the framework of the federal structure.

Overall, Germany's policy mix addresses all five ERA priorities. In fact, **increasing the effectiveness of the national research system** has been at the core of the policy agenda. Competitive funding plays thus an increasing role. Assessments / peer reviews are performed at (1) indi-

69 Depending on the design of the incentive, estimations for the costs vary between €460m and €5.7b. See: Elschner, Ernst, Spengel (2011).

70 See: *Bildung und Forschung in Zahlen* 2012, p. 66 (in OECD comparison, Germany is catching up, but remains still lacking behind its main peers.

vidual research performance level, (2) at programme level, as well as (3) at research institutions' level. For instance, the Institute for Research Information and Quality Assurance (iFQ) is monitoring any initiative launched and/or commissioned by the German Research Foundation (DFG).

In Germany, EU level instruments are used for national goals and there are attempts to influence the European level policy with core ideas as set out e.g. in the German "Internationalisation Strategy" and the "High Tech-Strategy 2020" thus, in general, seeking to ensure **optimal trans-national co-operation and competition**. In fact, the importance of international cooperation – especially with regard to solving the "grand challenges" – has been highlighted and reinforced in the High-Tech-Strategy 2020 (revised strategy released in 2010). Moreover, there have been notable steps towards a more functional "horizontalisation" at national level, i.e. European involvement is becoming part of the strategic thinking and there is a stronger awareness of European issues across all ministries (e.g. visible in ERA-Net participations and a generally strong participation in all new multilateral joint initiatives at the European level). Another example is the "Initiative on Multilateral Research Funding" was established in 2010 under the leadership of the German Research Foundation (DFG). Furthermore, there is a growing number of bi-/multilateral agreements on cooperation and joint activities in terms of R&D and innovation (and education).

With regard to **more open labour market for researchers**, Germany has undertaken significant efforts to facilitate researchers' mobility, for instance, by adopting in 2012 the "Anerkennungsgesetz" (recognition of foreign professional qualifications) and by drafting the "Mobility Strategy 2020". In general, vacancies and grants are increasingly announced internationally which is a step towards further opening up the German labour market for researchers and thus stimulating mobility (researchers' migration). In the same direction work some German efforts with regard to more mobility-friendly conditions of the existing social security systems, tax and pension schemes. All this seeks to enhance the attractiveness of academic careers in general and, moreover, the attractiveness of Germany for foreign researchers. A number of comprehensive bi-/multilateral collaboration agreements have been signed in order to further improve the open market for researchers (beyond the borders of Germany). The BMBF will be establishing a central office for international vocational training cooperation at the Federal Institute for Vocational Education and Training (BIBB). See in this regard, for instance, the "Memorandum on European Alliance for vocational training" (adopted in 12/2012, partners: Germany Spain, Greece, Portugal, Italy, Slovakia, and Latvia).

Gender equality and gender mainstreaming in research and in this regard the improvement of equal opportunities has been included as a central goal of all large-scale initiatives of the BMBF: the Initiative for Excellence, the Higher Education Pact 2020, and the Joint Initiative for Research and Innovation. In fact, excellence, quality, and equal opportunities are integral parts of German policy and are due to be considered as a universal guiding principles in all political decisions including in the drafting and implementation of programmes and measures, in the allocation of funding, and in the corresponding evaluation procedures. In this regard, as key strategic areas are set out: (1) Women in academia, (2) Business start-ups by women, (3) Research on gender related issues in education and research, and (4) International issues. The BMBF has created an 'Equal Opportunities in Education and Research Division' which has the task of implementing these key strategic areas (the Unit is part of the BMBF's Strategies and Policy Issues Directorate-General). It analyzes the need for action in education and research, supports strategic measures and projects, and works closely with all the BMBF's specialist directorates-general and divisions, as well as with all stakeholders in this area.

Circulating research knowledge and transferring it into markets and products will be crucial for maintaining the productivity of the German economy. There is common understanding that all this creates and preserves jobs and helps to ensure Germany's prosperity. Germany has launched and/or is internationally involved in a number of activities which tackle **optimal circulation, access to and transfer of scientific knowledge** (including via digital ERA). The main (frame-giving) political initiatives are: Digital Germany 2015 (new ICT Agenda), Pact for Research and Innovation, Initiative for Excellence, and the High-Tech-Strategy 2020.

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LIST OF ABBREVIATIONS

AiF	Arbeitsgemeinschaft industrieller Forschungsvereinigungen "Otto von "Guericke" (German Federation of Industrial Research Associations)
AvH	Alexander von Humboldt Foundation
BERD	Business Expenditures for Research and Development
BMBF	Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research)
BMWI	Bundesministerium für Wirtschaft und Technologie (Federal Ministry of Economics and Technology)
CHE	Centre for Higher Education
ERA	European Research Area
DAAD	Deutscher Akademischer Austausch Dienst (German Academic Exchange Service)
DESY	Deutsches Elektronen Synchrotron (German electron synchrotron)
DFG	Deutsche Forschungsgemeinschaft (German Research Foundation)
EFI	Expertenkommission Forschung und Innovation (Experts Commission for Research and Innovation)
EIB	European Investment Bank
ERA-NET	European Research Area Network
ESFRI	European Strategy Forum on Research Infrastructures
ETP	European Technology Platform
EU	European Union
EU-27	European Union including 27 Member States
FhG	Fraunhofer-Gesellschaft (Fraunhofer Society)
FAIR	Facility for Antiproton and Ion Research
FP	European Framework Programme for Research and Technology Development
FP7	7th Framework Programme
GBAORD	Government Budget Appropriations or Outlays on R&D
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on R&D
GOVERD	Government Intramural Expenditure on R&D
GWK	Gemeinsame Wissenschaftskonferenz (Joint Science Conference)
HEI	Higher education institutions
HERD	Higher Education Expenditure on R&D
HGF	Helmholtz-Gemeinschaft Deutscher Forschungszentren (Helmholtz Association)
HRK	Hochschulrektorenkonferenz (German Rectors' Conference)
HRST	Human Resources in Science and Technology
IGF	Industrielle Gemeinschaftsforschung (industrial collective research)
IP	Intellectual Property
ISCED	International Standard Classification of Education
MINT	Mathematics, Information technology, Natural sciences and Technology
MPG	Max-Planck-Gesellschaft (Max Planck Society)
OECD	Organisation for Economic Co-operation and Development
PRO	Public Research Organisations
PVA	Patentverwertungsagentur (patent commercialisation agency)
R&D	Research and Development
R&D&I	Research and development and Innovation
RI	Research Infrastructures
S&E	Science and Engineering
S&T	Science and technology

SME	Small and Medium Sized Enterprise
VC	Venture Capital
VIP	Validation of Innovative Potential of Scientific Research
WGL	Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz (Leibniz Association)
WR	Wissenschaftsrat (German Council of Science and Humanities)
XFEL	European X-Ray Laser Project
ZIM	Zentrales Innovationsprogramm Mittelstand (Central Innovation Programme for SMEs)

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Abstract
This analytical country report is one of a series of annual ERAWATCH reports produced for EU Member States and Countries Associated to the Seventh Framework Programme for Research of the European Union (FP7). The main objective of the ERAWATCH Annual Country Reports is to characterise and assess the performance of national research systems and related policies in a structured manner that is comparable across countries.
The Country Report 2012 builds on and updates the 2011 edition. The report identifies the structural challenges of the national research and innovation system and assesses the match between the national priorities and the structural challenges, highlighting the latest developments, their dynamics and impact in the overall national context. They further analyse and assess the ability of the policy mix in place to consistently and efficiently tackle these challenges. These reports were originally produced in December 2012, focusing on policy developments over the previous twelve months.
The reports were produced by independent experts under direct contract with IPTS. The analytical framework and the structure of the reports have been developed by the Institute for Prospective Technological Studies of the Joint Research Centre (JRC-IPTS) and Directorate General for Research and Innovation with contributions from external experts.

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As the Commission's in-house science service, the Joint Research Centre's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle.

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Key policy areas include: environment and climate change; energy and transport; agriculture and food security; health and consumer protection; information society and digital agenda; safety and security including nuclear; all supported through a cross-cutting and multi-disciplinary approach.

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