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JRC SCIENCE FOR POLICY REPORT

RIO COUNTRY REPORT 2015: Germany

Wolfgang Sofka
Maren Sprutacz

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Abstract

The 2015 series of RIO Country Reports analyse and assess the policy and the national research and innovation system developments in relation to national policy priorities and the EU policy agenda with special focus on ERA and Innovation Union. The executive summaries of these reports put forward the main challenges of the research and innovation systems.

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Foreword

The report offers an analysis of the R&I system in Germany for 2015, including relevant policies and funding, with particular focus on topics critical for EU policies. The report identifies the main challenges of the German research and innovation system and assesses the policy response. It was prepared according to a set of guidelines for collecting and analysing a range of materials, including policy documents, statistics, evaluation reports, websites etc. The quantitative data is, whenever possible, comparable across all EU Member State reports. Unless specifically referenced all data used in this report are based on Eurostat statistics available in February 2016. The report contents are partly based on the RIO country report, 2014 (Sofka, 2015).

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Executive summary

Context

The German economy was relatively unscathed by the 2008-2009 crisis, partly as a result of a strong export sector. Real GDP in Germany rose by 1.6% in 2014 and it was driven mainly by domestic demand. Since 2012 domestic demand has been the main contributor to GDP growth and is expected to remain so in the coming years. GDP is expected to increase by 1.5-2.0% in 2015-2016¹.

Both the federal and the Laender governments have committed themselves to balanced budgets. Since 2012 the German budget has recorded surpluses, the strongest (0.3%) in 2014. Continued smaller surpluses (0.2%) are projected for 2015-2016. The debt-to-GDP ratio is expected to fall steadily from 74.9% in 2014 to 69% by the end of 2016. Public spending on R&I was not decreased during the years of crisis. On the contrary, it has expanded significantly (in nominal terms) since 2005, thus providing a stable and predictable framework for R&D performers. Funding was inter alia also focused on leveraging private investment. The 2015 Council Recommendations advise Germany to continue using the available fiscal potentials for increased investments in research and education (European Commission, 2015a),

Germany has the largest Research and Innovation (R&I) system in Europe and the EU Innovation Union Scoreboard 2015 classifies Germany as an innovation leader member state together with Sweden, Denmark and Finland. Gross R&D expenditures (GERD) in Germany have reached €83.9b in 2014 or 2.87% of GDP, well within reach of its 3% goal. GERD in Germany amounts to almost 30% of all R&D expenditures in EU-28, while Germany accounts only for 16% of EU population and 21% of GDP. Public R&I in Germany benefits from a system of research in universities as well as in non-university research organisations which capture all aspects of research from basic to applied types. The latter have been benefitting from increasing budgets and stable planning conditions as part of the Pact for Research and Innovation. They provide a dynamic element to the German R&I system because of their ability to respond to changing research opportunities and requirements through internally competitive funding allocation mechanisms which distribute institutional funds from the government among their institutes and encourage competitive research initiatives. In general, funding for public R&I in Germany (also through the German Research Foundation, DFG) is becoming more competitive in nature and programme evaluations become increasingly comprehensive and institutionalised.

In terms of private R&I, budgets for R&D are increasing and have reached 1.95% of GDP in 2014. Firms in high and particularly medium-high tech manufacturing sectors, such as automotives, machinery and equipment, electric equipment, chemicals as well as pharmaceuticals, are the largest R&D investors. Eight of the 50 largest R&D investors in 2015 worldwide are headquartered in Germany. Then again, the participation and investment of the particularly important SMEs ('Mittelstand') in innovation in Germany has been eroding over time.

In 2015 major policy decisions on R&I in Germany from the previous year began to bear fruit. The change of Article 91b of the constitution in December 2014 provides new opportunities for the Federal Government to become a permanent partner in the financing of universities in collaboration with the Laender. Federal and Laender governments also agreed in 2014 to continue the Pact for Research and Innovation directed at funding increases for research organisations as well as the Higher Education Pact directed at funding education and research at universities until 2020. Both parties have also signalled their intention to extend the Initiative for Excellence directed at promoting excellent research in Germany beyond 2017 after comprehensive evaluation.

¹ European Commission Winter 2015 Economic Forecast

This development occurs against the backdrop of a strategy for balanced budgets of federal and Laender governments.

Key developments in the R&I system in 2015 included:

- Reform of the law for temporary employment in science ('Wissenschaftszeitvertragsgesetz') which now ties the duration of the employment contact directly to the desired level of qualification.
- Take over the financial responsibility for the student subsistence grants ('BAfoeG') by the Federal Government beginning 2015. Laender are supposed to use the newly available budgets of €1.2b annually for funding higher education.
- New programme „Innovation for production, service and work for tomorrow" focusing on positive employment effects from digital production and services with a budget of €1b until 2020.
- Proposal for a reform of procurement law ('Vergaberechtsmodernisierungsgesetz – VergRModG') as part of a bureaucracy reduction initiative in 2015 ('Bürokratienteilastungsgesetz'). The law would establish innovation as part of procurement decision making.
- Launch of a new roadmap process for research infrastructure by the Federal Ministry of Education and Research (BMBF). The process defines minimum investment costs (German share) as €50m per project (€20m in social sciences). Selected projects enter the national roadmap for research infrastructures with a timeframe until 2018.
- New research initiative "Kopernikus-Initiative" designed to support research in storage, transport and industrial usage of energy as well as the interaction between conventional and alternative sources of energy. BMBF will provide €120m in funding until 2018 and additional €280m until 2025.
- Launch of platform Industry 4.0 by BMBF. The platform organises interdisciplinary expert groups with members from politics, business, science and unions.

The commitment towards further strengthening and developing ERA is explicitly part of the coalition agreement of the Federal Government coalition in which it lays out its policy priorities until 2017. Accordingly, the Federal Government has formulated an ERA strategy complemented by the BMBF's action plan for international collaboration in 2014. The further improvement of framework conditions for research is addressed through increasing the quality of the science base for example through more structured doctoral trainings, improved employment laws as well as increased internationalisation and gender quality in research teams and grants.

Within the innovation aspect of R&I, Germany continues to improve the conditions for entrepreneurship by supporting entrepreneurship and improving the conditions for venture capital investors. German firms participate actively in open innovation activities and knowledge markets, with specialised providers of R&D services, such as research institutes gaining importance.

The identified challenges for Germany's R&I system are:

1. Counteracting the trend of declining innovation activities in German SMEs - German economy relies more than most other countries on a strong base of SMEs. Hence, the slowdown of innovation investment from this particular group of firm requires further insights and subsequent policy responses.
2. Improve framework conditions for and supply of venture capital - in EU comparison the venture capital market in Germany is underdeveloped and stagnant
3. Counteracting adverse trends in human capital availability - The human capital underlying the German R&I system is challenged by a disproportionately large share of soon to retire scientists and engineers and by a shift in the career choices of secondary school students.

In addition, the opportunities emerging from the change in constitution as well as from the new High-tech Strategy and the Digital Agenda 2014-2017 will require expert implementation. In Germany's complex R&I system with dispersed decision making a commitment to research excellence, efficient execution and comprehensive evaluation will be required to realise their potential.

In sum, the German R&I system performs well and has come close to reaching its goals. The system has been responsive to stakeholder demands and has made important changes which have increased R&I budgets as well as improved the quality of R&I. R&I in Germany moves towards addressing long-term challenges and exploiting new opportunities.

R&I Challenges

Challenge 1: Counteracting the emerging trend of declining innovation activities in SMEs

Description

Innovation in SMEs is a central part of all major R&I strategies and Germany's SME sector is highly developed and a fundamental pillar of the national innovation system. This is evidenced by high shares of SMEs innovating in-house and SMEs introducing product, process, marketing and organisational innovations. In terms of innovation outcomes, firms in Germany generated 13% of their sales from innovative products and services in 2012. This number is higher than the EU-28 average (11.9%).

However, this share has been declining when compared with 17.4% in 2008 and 15.5% in 2010. The EU Innovation Scoreboard 2015 also registered a downward trend for SME innovation indicators with fewer SMEs creating product or process innovations (-3.1%) as well as marketing or organisational innovations (-5.4%) compared to the previous year. This is particularly true for sales of new-to-market and new-to-firm innovations as share of turnover for which a downward trend has been registered over the past ten years. The decline registered for 2014 was -5.5% (European Commission, 2015c; Sofka, 2015). The expert commission advising the German government on matters of research and innovation (EFI Commission) also points to a decline in innovation intensity in SMEs, i.e. the percentage of a company's turnover that is spent on innovation, which almost halved from 2.7% in 1995 to 1.6% in 2012. Over the same period, innovation intensity in large German corporations rose from 3.0 to 4.5%. One of the drivers of this decline seems to be the lower overall level of innovation expenditure by those SMEs that only conduct research occasionally. Expenditure by SMEs that are continuously engaged in R&D has remained stable over the years. Moreover, trends in German corporate employment relevant to innovation show that, on average, the percentage of highly qualified engineers and scientists among the staff of small businesses (<100 employees) fell slightly from approximately 2.7 to 2.6% between 1999 and 2010. During the same period, the percentage of highly qualified staff rose slightly (from 3.8 to 4.2%) in medium sized companies (100 to 500 employees) and strongly (from 6.0 to 7.1%) in large companies (>500 employees). Knowledge intensification in the economy was thus concentrated mainly in large corporations (EFI, 2015).

Policy response

The reasons for the drop in the above mentioned indicators have yet to be identified and more research is required into cause and effect relationships before policies can be adjusted or refined (Sofka, 2015).

Assessment

This trend deserves high priority and political attention and more research into its underlying causes. Possible causes of the comparatively weak expenditure by SMEs include the decline in new business startups in the last few years – which may partly be an initial effect of demographic change - and the worsened situation for financing R&D activities in the wake of the financial and economic crisis. Another possible explanation is that the effects of skilled-labour shortages are much stronger for SMEs than for large corporations (EFI, 2015).

There is certainly no lack of attention to innovation in SMEs from the part of the policy maker but even though much has been done to create innovation friendly framework conditions, especially for SMEs, there have been calls to the German government to generally pursue a bolder innovation policy and to rise its target for R&D intensity to 3.5% of GDP (EFI, 2015).

Challenge 2: **Improve framework conditions for and supply of venture capital**

Description

The venture capital market in Germany is consistently and significantly smaller than in comparable countries and has been declining as a share of GDP over the past decade. The restricted availability of venture capital has been identified as a limiting factor for growth in high tech manufacturing and knowledge intensive services, which are fields that Germany seeks to develop (EFI, 2015; OECD, 2012; Voigt, 2014; Sofka, 2015). 20% of entrepreneurs in Germany reported difficulties in financing in 2014 which is relatively high in terms of historical comparison (KfW, 2015). In 2013 the venture capital market in Germany was 0.04% of GDP, down from 0.05% in 2012. The same year, other innovation leader EU member states, such as Denmark (0.1%), Finland (0.08%) and Sweden (0.08%) had significantly larger venture capital markets. The same is true for other large European economies such as UK (0.12%) and France (0.08%) (European Commission, 2015c).

In 2013, 174 concepts have received seed financing in Germany (€43.6m), 494 firms secured start-up financing (€355.4m) and 174 firms received later stage financing (€257.6m). Comparatively more firms in Germany receive seed financing (21% of venture capital financed firms and 7% of venture capital provided) compared with Europe (13% of venture capital financed firms and 3% of venture capital provided). Conversely, later stage venture capital financing is less pronounced in Germany (21% of venture capital financed firms and 39% of venture capital provided) when compared with Europe as a whole (29% of venture capital financed firms and 43% of venture capital provided (Sofka, 2015; EVCA, 2014).

There are a number of framework conditions which may limit the size of the market for venture capital in Germany, such as restrictive rules for how carried forward deficits ('Verlustvortrag') are treated in taxation or the value-added tax on funds management services make fund management comparatively costly. In contrast to many other countries, institutional investors, such as pension funds, that could serve as anchor investors are missing in Germany.

Policy response

Both active approaches in which government acts as a venture capital investor and passive approaches in which the government incentivises private investors are present. Many of the policies target entrepreneurship in high-tech sectors. "INVEST – grant for venture capital" which was introduced in 2013, reduces risk for early stage investors and business angels by reimbursing 20% of equity-capital investments in young innovative enterprises under certain conditions. Uncertainty about the tax treatment of the grant led to relatively low demand and in 2014 the subsidy was exempted from taxation – also retroactively for 2013 (EFI, 2015). The High-tech Start-Up Fund launched in 2005 is an investment fund for technology start-ups of the government, German government-owned development bank KfW as well as industrial partners. Its initial investment endowment in 2005 was €272m. Investments are limited to €500,000 and the fund provides access to coaches as well as venture capital investors for future investment rounds (Sofka, 2015). Another tool is the ERP-Startfonds which provides early stage equity financing of up to €5m for R&D intensive firms, leveraging matching investments from private lead investors. The Federal Government also announced that it intends to launch a fund with a volume of €500m via the European Investment Fund (EIF) to finance the growth of German start-ups (EFI, 2015).

Crowdfunding (or crowd investing) is still marginal but growing. The Federal Government has therefore proposed exceptions for small crowd investments from regulatory burdens (i.e. mandatory reporting to investors and related liabilities) under certain conditions (Sofka, 2015).

A law passed by the German parliament in 2008 to facilitate the transfer of carried-over losses (Law on the Modernisation of the Framework Conditions for Venture Capital and Equity Investments, MoRaKG) was rejected by the European Commission because of concerns relating to state aid and is still before the European Court of Justice (EFI, 2015). Repeated calls for higher taxes on the remuneration of fund initiators have been opposed by the Federal Government so far (EFI, 2015).

Assessment

Enhancing efforts in the fields of growth financing are essential to improve conditions for entrepreneurship in high tech sectors and knowledge-intensive services. In the context of framework conditions, unintentional consequences from regulatory changes, changes in taxation or discussed but not enacted changes should be avoided. The absence of private anchor investors has not yet been offset by public institutional investors. The lack of funding from pension funds makes it even more important that other institutional investors are active in this field. The efforts to create sizable institutional investor through EIF fund are promising.

Challenge 3: Counteracting adverse trends in human capital availability

Description

A lack of skilled personnel has been identified as one of the main emerging constraint facing the German R&I system (OECD, 2012; EFI, 2014; Voigt, 2014; Sofka, 2015). Two trends influence the human capital underlying the German R&I system. The first is rooted in an overall aging society and a large share of soon to retire scientists and engineers. Until 2030 more than half of today's highly skilled professionals without a university education will have left the workforce. Depending on the labour force participation rate, net immigration of between 346.000 and 533.000 people per year until 2050 will be needed to keep the working population stable (Bertelsmann Stiftung, 2015). The decline in new business start-ups in the last few years may also be linked to the onset of first effects of demographic change (EFI, 2015). The second trend stems from a shift in the career choices of secondary school students. The German R&I system has traditionally benefitted from a labour force in which innovation is not exclusively the task of university trained scientists and engineers but is based on a specific combination of highly qualified university graduates and highly skilled workers from the dual vocational education system. While in the mid-1960s, 92% of school leavers entered into vocational training and only 8% enrolled in university education, in 2011 the share of newly enrolled university students (50.1%) and the share of newly enrolled participants in dual training (49.9%) were almost equal. Among professions for which apprenticeship supply does not meet demand are several with relevance for R&I in Germany: Technicians (-10%), electrical technician (-10%) and IT (-11%). Today, also fewer dual educated workers advance to an engineering level through further education and training.

Numbers of students in STEM subjects have been increasing over the past years but dropout rates in STEM study programmes are seen as reducing the pool of qualified scientists, with 39% of university students in maths and natural sciences not finishing their studies.

Policy measures

The political will for Germany to maintain its solid mix of highly skilled workers and graduates from the tertiary education system certainly exists. Removal of barriers for skilled workers to enter tertiary education as well as increased support for students who decide to switch from academic training to vocational training are targets clearly reflected in the 2014 coalition agreement of the Federal Government. Recent policy initiatives focus on increasing the attractiveness of vocational training while at the same time moving away from envisioning it as the final step of professional training and

instead as a stepping stone to further, academic qualification. This is reflected in the "Promotion of Advancement through Training Act" which improves the permeability between vocational and academic education and encourages dual university careers (combining work with university education). The share of these dual careers is still small but increasing (Sofka, 2015). In October 2015, the Federal Government passed a reform of the "Promotion of Advancement through Training Act" part of which is an increase in the subsistence support for professional vocational training and advance training.

The opportunities to have foreign professional qualifications recognised in Germany have improved significantly through adoption of the "Recognition Act" in 2012. The issue of drop-out rates is addressed by the extension of the Higher Education Pact which includes for the first time dedicated funds for quality improvements increasing graduation rates. Moreover the Federal Government will make available approximately € 2bn by 2020 as part of the Quality Pact for Teaching in order to enhance the quality of teaching at institutions of higher education. This joint initiative of the Federal Government and the Laender governments was launched in 2011.

Assessment

There are calls to further increase the permeability between different educational tracks and to provide young people with low educational qualifications with additional entry-level and transitional measures for accessing the vocational education system. Future goals for the German educational system could focus on an optimal mix of different types of education and flexible individual educational paths, rather than the ratio of university graduates (EFI, 2014). Policy efforts to transform vocational training into stepping stones towards further academic training appear promising as are higher intake numbers of students in STEM fields. It is also a positive sign that with the extension of the pact, teaching quality and the reduction of dropout rates among students has become an explicit goal with dedicated funding. It remains unclear to what degree these improvements will be sufficient to address the challenge (Sofka, 2015).

1. Overview of the R&I system

1.1 Introduction

Germany is the largest country within the European Union in terms of population and gross domestic product (GDP). The country has 81.2 million inhabitants in 2015 and a GDP of €2,915.6b in 2014 (EUROSTAT).² GDP per capita in Germany (€35,400 in 2014) is significantly above the average of EU-28 of €27,400. In relative terms, 16% of the population of EU-28 live in Germany and 21% of EU-28 GDP is produced in Germany.

Germany had slow but positive GDP growth rates in 2012 (0.4%) and 2013 (0.3%) and growth has significantly picked up in 2014 with 1.6%. The growth rate of Germany has surpassed EU-28 average growth of 1.4% in 2014. The Federal Ministry for Economic Affairs and Energy ('Bundesministerium fuer Wirtschaft und Energie', BMWi) predicts a similar GDP growth rate of 1.5% for 2015 in its annual economic report ('Jahreswirtschaftsbericht', BMWi, 2015b).

Germany has largely achieved balanced budgets in 2012 (-0.1% of GDP) as well as in 2013 (-0.1% of GDP). The country has even achieved a budget surplus of 0.3% of GDP in 2014. Accordingly, overall government debt as a percentage of GDP continues to decline to 74.9% in 2014. The debt position of Germany compares favourably to the average of EU-28 which shows budget deficits of 3.0% of GDP in 2014 and government debt as a share of GDP of 86.8%. Labour market trends in Germany have also been positive in recent years. The unemployment rate has reached 5.0% in 2014 which is roughly half of the average of EU-28 (10.2%). Unemployment has continuously declined after 5.4% in 2012 and 5.2% in 2013.

Manufacturing sectors are important for the German economy. They accounted for 34.4% of total gross value added in 2013. In comparison, manufacturing sectors have a higher importance for the German economy than for the average of EU-28 with gross value added shares of 26.2% from manufacturing in 2012 (latest available year). Moreover, compared with the average economic structure of EU-28, Germany has a high percentage of employment in high- and medium-high tech manufacturing sectors. 9.8% of employees in Germany worked in such sectors in 2014 (EU-28 average: 5.7%). In terms of employment in knowledge intensive sectors, Germany (2014: 39.7% of employment) is fairly aligned with the average of EU-28 (2014: 39.8%).

Gross R&D expenditures (GERD) in Germany have reached €83.9b in 2014 or 2.88% of GDP.³ GERD in Germany amounts to almost 30% of all R&D expenditures in EU-28. GERD has grown by 20% between 2010 and 2014. Government budget appropriations or outlays for research and development (GBAORD) amount to €25.4b in 2014 which is 5.4% higher than in 2012. Business expenditures on R&D (BERD) account for 1.95% of GDP in 2014 which is slightly higher than in 2013 (1.9%). The relationship between government and private R&D investment in Germany is very stable over the years with two thirds (68% in 2014) being performed by the private sector. Investments in R&D by both government and private sector in Germany have consistently increased even in times of severe economic stress from financial and economic crises.

In terms of innovation outcomes, firms in Germany generated 13% of their sales from innovative products and services in 2012 (latest available year). This number is higher than the EU-28 average (11.9%). However, this share has been declining when compared with 17.4% in 2008 and 15.5% in 2010. The European Commission classifies Germany in its Innovation Scoreboard 2015 (European Commission, 2015c) as an innovation leader. The leader position indicates that country innovation performance is

² If not referenced otherwise, all quantitative indicators are based on EUROSTAT data.

³ EUROSTAT started publishing GDP data according to the ES 2010 standard in September 2014. Following the new calculation standard GDP in Germany is slightly higher which implies that R&D as a share of GDP is slightly lower.

at least 20% above EU-28 average. Germany is overall ranked fourth within Europe and shares the innovation leader status with Sweden, Denmark and Finland.

Germany follows a target of 3% of GDP being invested in R&D with two thirds stemming from the business sector (NRP, 2015). This goal is well within reach with 2.88% in 2014. The funding contribution of the private sector has been very consistently around the 66% mark. It is likely that Germany will reach the 3% goal in 2020. The Expert Commission on Research and Innovation (EFI) suggests that the goal is not ambitious enough and that a goal of 3.5% would be more appropriate (EFI, 2015).

The economic and political context has been positive for R&I in Germany in 2015. The current Federal Government is formed by a coalition of Christian Democratic Parties (CDU/CSU) and the Social Democratic Party (SPD) and led by Chancellor Angela Merkel since September 2013. The coalition holds a broad majority of 504 of the 631 seats in parliament. At least one of the coalition parties of the Federal Government is also part of the governments in all 16 states (so-called 'Laender'). This implies that the potential for policy making which requires consensus between Federal and Laender governments is high. Federal and Laender government have reached important agreements. Among the most important ones is the change to the constitution (Art. 91b GG 'Grundgesetz') enacted in December 2014 which enables the Federal Government to fund R&I in higher education permanently (Deutscher Bundestag, 2014). Federal and Laender governments have also agreed to extend important policy programmes for the funding of non-university research organisation ('Pakt für Forschung und Innovation') as well as the Higher Education Pact ('Hochschulpakt') for universities until 2020.⁴ These political decisions have been welcomed by important stakeholders such as the Expert Commission on Research and Innovation (EFI) (EFI, 2015).

Table 1 Main R&I indicators 2012-2014

Indicator	2012	2013	2014	EU average (2014)
GDP per capita	33,600	34,400	35,400	27,400
GDP growth rate	0.4	0.3	1.6	1.4
Budget deficit as % of GDP	-0.1	-0.1	0.3	-3.0
Government debt as % of GDP	79.7	77.4	74.9	86.8
Unemployment rate as percentage of the labour force	5.4	5.2	5.0	10.2
GERD in €b	79.1	79.7	83.9	284 (total for EU-28)
GERD as % of the GDP	2.87	2.83	2.88	2.03
GERD (EUR per capita)	966.6	972.1	1,030	560
Employment in high- and medium-high-technology manufacturing sectors as share of total employment	9.7	9.6	9.8	5.7
Employment in knowledge-intensive service sectors as share of total employment	40.5	39.6	39.7	39.8 (2013)

⁴ <http://www.gwk-bonn.de/fileadmin/Papers/PFI-III-2016-2020.pdf> (8/2015)

Indicator	2012	2013	2014	EU average (2014)
Turnover from innovation as % of total turnover	17.4 (2008)	15.5 (2010)	13.0 (2012)	11.9 (2012)
Value added of manufacturing as share of total value added	34.8	34.4	n.a.	26.2 (2012)
Value added of high tech manufacturing as share of total value added	2.8	2.8	n.a.	2.5 (2012)

Download: 15 December 2015. GERD of 2014 for Germany and EU-average are estimations, updated in May 2016.

1.2 Structure of the national research and innovation system and its governance

1.2.1 Main features of the R&I system

Germany has an R&I system of multiple layers and institutional pillars. The German R&I infrastructure is broadly developed encompassing virtually all disciplines, a large number of research facilities and skilled personnel. The German R&I system has two primary features which add to its complexity. First, R&I responsibilities are shared by the Federal Government as well as by the governments of the 16 German states ('Bundeslaender' or 'Laender' for short). Second, and overlapping with the first factor, research is not just conducted in universities and companies but also at non-university institutes and universities of applied sciences. There exist more than 800 publicly funded research institutions in Germany and numerous R&D centres of companies. Many of these institutions collaborate in topical networks or regional⁵.

Much of publicly funded research is conducted in a well-established university system and in non-university public research institutes. The latter are mostly organized in the large research organisations: Max Planck Society (MPG), Fraunhofer Society (FhG), Helmholtz Association (HGF), and Leibniz Association (WGL). Roughly two thirds of R&D spending in Germany originate from the private sector. R&I in the private sector is especially strong in medium high-tech industries, like automotive production, machinery and equipment and chemicals. R&D and its commercial exploitation in successful innovation is a major component of the strategy of many German firms as evidenced by the Innovation Union Scoreboard 2015 (European Commission, 2015c). Stifterverband (2015c) reports that the business sector in Germany invested €53.6b in 2013 in R&D. 9.6% of these R&D investments stem from firms with fewer than 250 employees, another 5% from firms with more than 250 employees but less than 500. 5 % of R&D in the business sector is financed from abroad. The highest contributions from abroad occur in the size classes between 1,000 and 2,000 employees (15.5%), between 2,000 and 5,000 employees (21%) as well as between 5,000 and 10,000 employees (15.5%)⁶.

Finally, the German R&I system also includes specialized service providers which consult, support and manage R&D and innovation in various ways. Such services include technology transfer, IPR consulting or innovation marketing. Such services are available throughout the country and add to the dynamic of research and innovation in Germany⁷.

⁵ For a complete overview see: <http://www.germaninnovation.org/research-and-innovation/german-research-landscape> (8/2015)

⁶ Data source Stifterverband (2015c), own calculations.

⁷ <http://www.germaninnovation.org/research-and-innovation/centers-of-innovation-in-germany> (8/2015)

1.2.2 Governance

Decision making on R&I in Germany has been very stable and predictable in recent years. R&I is a shared responsibility of both the Federal Government and the Laender. At the national level, the Federal Ministry of Education and Research (BMBF) covers most of the responsibilities for research policy. The Federal Ministry of Economics and Energy (BMWi) is also involved in some areas of innovation and technology policy. A number of other ministries have own research institutes ('Ressortforschungseinrichtungen'). These institutes provide ministries with specifically relevant scientific knowledge or assess quality or safety standards.

In contrast, education policy is the responsibility of the Laender governments with few exceptions. The Laender fund the universities in their state and co-fund Max Planck Society, Fraunhofer Society, Helmholtz Association, and Leibniz Association. The Laender also play a very active role in facilitating knowledge transfers between science and industry as well as other innovation programmes.

Federal and Laender governments coordinate joint initiatives through the Joint Science Conference ('Gemeinsame Wissenschaftskonferenz', GWK). It encompasses the ministers and senators of the Federal Government and the Laender responsible for science and research as well as for finance. Indicating stability in decision making on the German R&I system, GWK has agreed in October 2014 to continue ambitious policy programmes which were about to expire: Pact for Research and Innovation ('Pakt für Forschung und Innovation') as well as the Higher Education Pact ('Hochschulpakt') until 2020, GWK has also signalled to extend the Initiative for Excellence ('Exzellenzinitiative') beyond 2017⁸.

The federal parliament ('Bundestag') as well as the representation of the Laender ('Bundesrat') have approved a change to the constitution (Art. 91b GG 'Grundgesetz') in December 2014 with significant consequences for the German R&I system. The Federal Government is now in a position to make agreements with individual Laender and fund R&I in higher education permanently. Laender can still object agreements since the new law requires unanimous approval of all Laender (Deutscher Bundestag, 2014). A goal of the revised law to find agreements between Federal and Laender governments is to develop distinctive profiles in R&I. Both the extension of the "Pact" programmes and the change in constitution has been called for and welcomed by institutions such as the Expert Commission on Research and Innovation (EFI, 2015).

Decision making on R&I in Germany encompasses multiple years and is based on comprehensive strategy considerations. Examples include the renewal of the High Tech Strategy ('Hightech-Strategy 2020', BMBF, 2014d) as well as the Digital Agenda 2014-2017 (BMWi, 2014a). The latter provides also an example for the inclusion of various stakeholders. The Digital Agenda 2014-2017 is accompanied by the establishment of a Council for Information Infrastructure ('Rat fuer Informationsinfrastrukturen') as an advisory committee and for the development of recommendations. This council has been established in November 2014 and consists of eight representatives of scientific users, eight representatives of organisations such as libraries and archives, four representatives of public life and four representatives of Federal and Laender governments⁹.

Main implementation bodies include the German Science Foundation (DFG) which is the self-governing organisation for science and research in Germany. DFG is mostly in charge of conducting a competitive process through which the best fundamental research projects from scientists of universities and research institutions receive funding. It covers both natural sciences and humanities. The promotion of applied R&D for small and medium-sized enterprises (SMEs) is among others the responsibility of the German Federation of Industrial Research Associations "Otto von Guericke" (AiF), which acts as

⁸ <http://www.gwk-bonn.de/fileadmin/Papers/PFI-III-2016-2020.pdf> (8/2015)

⁹ <http://www.bmbf.de/press/3678.php> (8/2015)

the administration body of the Industrial Cooperative Research Programme ('Industrielle Gemeinschaftsforschung' IGF) and of the Central Innovation Programme for SMEs ('Zentrales Innovationsprogramm Mittelstand' ZIM).

The research organisations Max Planck Society, Fraunhofer Society, Helmholtz Association, and Leibniz Association are a unique feature of the German R&I system. Their institutes cover a broad spectrum from basic to applied research and act as providers of research services. Many directors of research institutes are also chaired university professors. A particularity of the German R&I system is also the presence of funding management agencies ('Projekttraeger', PRO) which are typically located at larger research institutes. Their role is to administer and manage the R&D programmes funded by ministries. Universities and research institutes can be interlinked.

Evaluations are part of all major R&I policy schemes in Germany. Evaluations occur regularly, at all levels and through qualified bodies of experts. Many of these evaluation and monitoring reports provide important inputs and insights for this report. Evaluations have significant influence on how programmes change and develop. For example, the BMWi programme 'EXIST' was created in 1998 with the goal of fostering entrepreneurship from scientists and researchers. It has since undergone important changes with regard to funding recipients, instruments and approaches as a reflection of continuous monitoring and impact evaluations (Kulicke, 2014).

Evaluation of the German R&I system as a whole is conducted most comprehensively by the Expert Commission on Research and Innovation (EFI). The German Council of Science and Humanities '(Wissenschaftsrat') conducts evaluations and provides counselling for Federal and Laender governments. Examples include its recent "Science-driven Evaluation of Large Research Infrastructure Projects for the National Roadmap"¹⁰. More information on the evaluation process can also be found in section 2.2.1 of this report.

1.2.3 Research performers

Public research in Germany is conducted in both universities and research institutes. Universities received €30.9b in 2012 for both teaching and research (BMBF, 2015c). An important part of public research in Germany is conducted in research institutes which are organized in research organisations. These research organisations capture the full range of research from basic to applied types. The main non-university research organisations are Max Planck Society (MPG) with a budget of €1.8b in 2014, Fraunhofer Society (FhG) with a budget of €2b in 2014, Helmholtz Association (HGF) with a budget of €4b in 2014 and Leibniz Association (WGL) with a budget of €1.4b in 2014 (GWK, 2015). The research organisations accounted for a combined 1,100 patent filings with the European Patent Office (EPO) in 2010 compared with 552 filings from German universities (Dornbusch and Neuhausler, 2015). However research in universities and research organisations is not strictly separated. 1,125 employees of the research organisations had co-appointments as university professors in 2014 (2010: 745) (GWK, 2015). Besides, the German Research Foundation (DFG) had a budget €2.9b in 2014 to fund research projects of individual researchers as well as universities and research institutes (GWK, 2015).

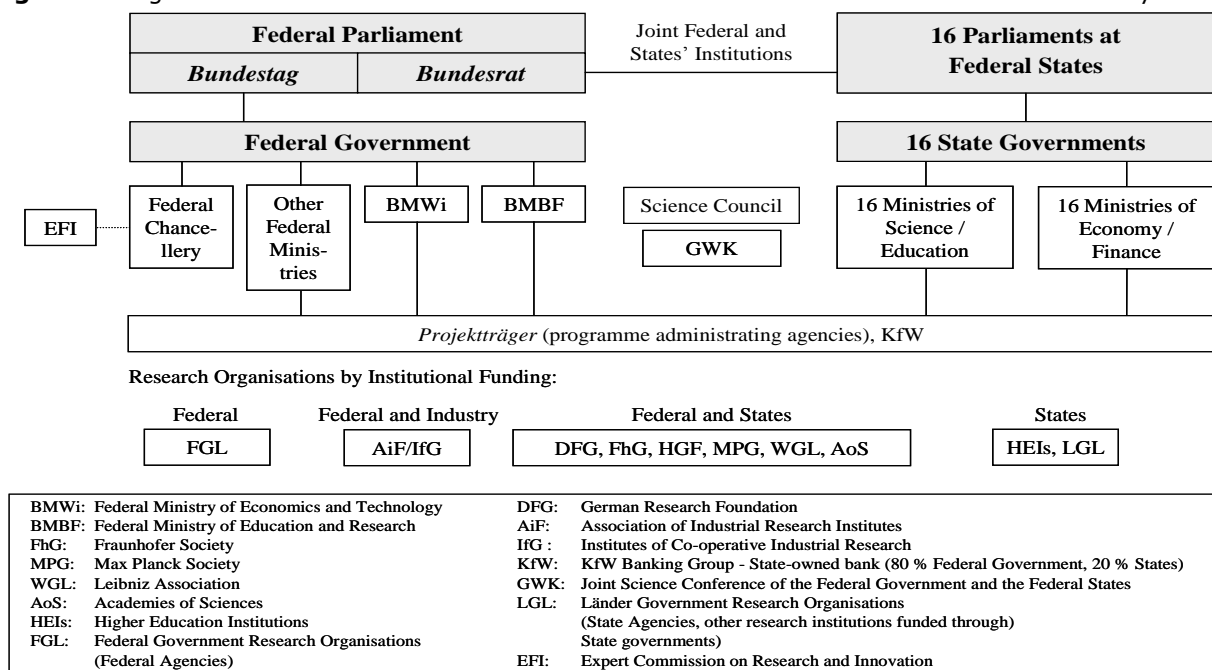
Two thirds of R&D in Germany is consistently funded by the private sector. German firms invested €53.6b in internal R&D in 2013 and particularly strong contributions stem from medium-high tech manufacturing sectors (BMBF, 2015c). The largest R&D investments originate from firms manufacturing motor vehicles (2013: €17.2b), electrical and optical machinery (2013: €7.3b), machinery and equipment (2013: €5.4b) as well as the pharmaceutical (2013: €4.1b) and chemical industries (2013: €3.3b) (BMBF, 2015c). The automotive sector in Germany is a particularly important contributor to R&D. It accounts for three quarters of all R&D investment in this sector in Europe and has

¹⁰ http://www.wissenschaftsrat.de/download/archiv/2841-13_engl.pdf (8/2015)

increased R&D investments by 9.7% in 2013 (European Commission, 2014c). Volkswagen is the worldwide number one of all firms with R&D investments reaching €11.7b or 6% of sales in 2013 (European Commission, 2014c). Other large R&D investing firms headquartered in Germany among the top 50 in 2014 worldwide include Daimler (14th worldwide), BMW (21), Robert Bosch (17), Siemens (24), Bayer (29), Boehringer Ingelheim (44) and SAP (50). (European Commission, 2015d).

Apart from these large R&D investors, Germany has a very active base of innovative small and medium sized firms (SME) ('Mittelstand'). 38.6% of SMEs in Germany are innovating in-house compared with an average of EU-28 of 28.7% as reported by the EU Innovation Union Scoreboard 15 (European Commission, 2015c). 14.6% of employees work in knowledge-intensive activities (European Commission, 2015c). The importance of R&D investment from abroad in Germany is at a moderate level. 26.2%¹¹ of business R&D expenditures stem from foreign-controlled affiliates (OECD, 2010). 4.3% of R&D expenditures in Germany were financed from abroad in 2012, which is below EU-28 average (9.8%) but a significant increase compared with 2.3% in 2003 (Schasse and Leidmann, 2015).

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



Source: Pro-INNO (2011).

¹¹ 2007 latest available year.

2. Recent Developments in Research and Innovation Policy and systems

2.1 National R&I strategy

The most comprehensive R&I strategy document in Germany is the new high-tech strategy ('Neue Hightech-Strategy', BMBF, 2014d) enacted by the Federal Government in September 2014 covering the legislative period until 2017. The new high-tech strategy builds on an R&I strategy process which started in 2006. It is a comprehensive strategy framework covering research, education, innovation and technology transfer topics in Germany. The Federal Government has invested up to €27b between 2006 and 2013 as part of this strategy (BMBF, 2014c). The new high-tech strategy combines both research and innovation along five central themes which are supposed to be accomplished as a concerted effort across ministries. The five themes are:

- Priority for six future challenges with major opportunities for economic growth and prosperity: Digital economy and society, sustainable economy and energy, innovative employment, healthy living, intelligent mobility as well as civil security.
- Improved transfer of knowledge between science and business, nationally and internationally.
- Increased innovation dynamic especially in new firms as well as SMEs.
- Improved framework conditions for satisfying the demand for skilled scientists and engineers.
- Intensified dialogue with society.

Part of the new high-tech strategy process is a newly created expert group, the so called High-Tech Forum started in 2015¹². It consists of 20 high-level representatives from academia, industry and civil society. The goal of the High-Tech Forum is to develop strategy as well as implementation recommendations for accomplishing the goals of the new high-tech strategy. The forum is organized in eight subject forums ('Fachforum') addressing particular topics. The subject forums internationalisation ('Fachforum Internationalisierung') as well as autonomous systems ('Fachforum Autonome Systeme') have provided interim reports in November 2015¹³. The former emphasized the importance of both research and innovation. Additionally, it clarified its structuring principles along three dimensions: excellence of German R&I abroad, attractiveness of Germany for R&I from abroad as well as the positioning of Germany in international networks. The latter subject forum "autonomous systems" highlighted its intention to develop not just recommendations for new technological and business models originating from autonomous robots or vehicles but also necessary societal and legal framework conditions.

The new high-tech strategy is aligned with EU priorities. It explicitly refers to opportunities and complementarities with the EU framework program "Horizon 2020" as well as the European Research Area (ERA). In particular the issues of cross-border co-operation or joint programming are addressed in dedicated policy papers on the European Research Area of the Federal Government ('Strategie der Bundesregierung zum Europäischen Forschungsraum', BMBF, 2014g) as well as an action plan for international co-operation ('Aktionsplan Internationale Kooperation', BMBF, 2014a).

The strategy process is actively accompanied, analysed and discussed by the Expert Commission on Research and Innovation ('Expertenkommission Forschung und Innovation', EFI). The commission consists of 5 professors of German universities and 1 professor of Swiss universities. In its annual report for 2015 it highlights the following recommendations for the new high-tech strategy (EFI, 2015):

¹² <http://www.hightech-forum.de/> (8/2015)

¹³ http://www.stifterverband.org/pressemitteilungen/2015_11_12_high-tech-forum (1/2016)

- Incorporate concrete and transparent milestones for the implementation of the strategy.
- The concept of “social innovation” is a welcome extension of the innovation construct but requires precise definition to facilitate unambiguous, criteria-based policy development.
- Political considerations concerning regional participation should not guide the R&I policies of the Federal Government.
- The focus on overarching topics and the definition of goals instead of means should be kept and extended to facilitate fruitful competition among approaches and potential solutions.
- The new high-tech strategy encourages universities to experiment and innovative with new forms of regional collaboration. It is desirable to achieve complementarity with the instruments of the Initiative for Excellence (‘Exzellenzinitiative’).
- Transparency and participation of citizens and society can be strengthened through internet-based platforms.
- The new high-tech strategy should be extended with a systematic monitoring system.
- Evaluation should become an integrative part of any R&I policy development.

2.2 R&I policy initiatives

The New High-tech Strategy (BMBF, 2014d) and the Digital Agenda 2014-2017 (BMW, 2014a) have provided R&I policy initiatives in Germany with priorities and integrative principles. They encompass both demand and supply policy instruments as well as links between research and education, e.g. in addressing opportunities and challenges emerging from increasingly decentralized but interconnected production processes (Industry 4.0). Among recent R&I policy initiatives two are of particular importance.

First, Federal and Laender governments have changed the constitution (Art. 91b GG ‘Grundgesetz’) in December 2014 (see also section 1.2.2 of this report) (Deutscher Bundestag, 2014). Previously, Laender governments were responsible for the funding of universities and the Federal Government could only provide funds through temporary, topical programmes. Following the change in constitution, the Federal Government can now negotiate agreements with individual Laender governments and fund R&I in higher education permanently. Laender can still object agreements since the new law requires unanimous approval of all Laender (Deutscher Bundestag, 2014). These agreements are supposed to facilitate distinctive R&I profiles of Laender universities. This change in the constitution has been called for repeatedly and consistently by R&I representatives in Germany such as the Expert Commission on Research and Innovation (EFI, 2015). Accordingly, the agreements between Federal and Laender governments have significant potential to strengthen the German R&I system. The realisation of these potentials will depend on the implementation.

Second, R&I in Germany has benefitted from so-called pacts between Federal and Laender governments for increased funding of research and university education. These pacts encompass:

- Initiative for Excellence (‘Exzellenzinitiative’): Policy package to foster elite research in universities funded by both the Federal Government (75%) and the states ‘Laender’ (25%) (Budget 2012-2017: €2.7b)¹⁴,
- Higher Education Pact (‘Hochschulpakt’): Policies to increase (a) quantity as well as quality of university education and (b) the international competitiveness of university research (Budget 2011-2015: €7b of the Federal Government with a similar commitment of the Laender¹⁵,

¹⁴ http://www.dfg.de/foerderung/programme/exzellenzinitiative/allgemeine_informationen/index.html and <http://www.gwk-bonn.de/fileadmin/Papers/Exzellenzvereinbarung-II-2009.pdf> (9/2015)

¹⁵ <http://www.bmbf.de/de/6142.php> and <http://www.gwk-bonn.de/fileadmin/Papers/HSPA-II-BLV-2013.pdf> (9/2015)

- Pact for Research and Innovation ('Pakt für Forschung und Innovation'): Stabilize and increase funding for research organisations (Fraunhofer-Gesellschaft, Helmholtz-Gemeinschaft, Max-Planck-Gesellschaft und Leibniz-Gemeinschaft, Deutsche Forschungsgemeinschaft) with 5% annual funding increases (Total institutional funding 2012: €7b)¹⁶. The funding will increase by 3% annually starting in 2016.

Federal and Laender governments have agreed in December of 2014 to extend important policy programmes for the funding of non-university research organisations ('Pakt für Forschung und Innovation') as well as the Higher Education Pact ('Hochschulpakt') for universities until 2020¹⁷. The latter extension is designed to provide 760,000 new students (compared with 2005) with higher education. For this purpose the Federal Government will provide €9.9b and the Laender €9.4b (NRP, 2015). An important change in the Higher Education Pact is the introduction of dedicated funds for quality improvements increasing graduation rates (10% of total funds). Part of the Higher Education Pact 2020 is also that universities will see an increase of their lump-sum allowance for indirect project costs ('DFG Programmpauschale') of grants from the German Science Foundation (DFG) from 20% to 22% starting in 2016¹⁸. The Laender will cover the additional 2% while the Federal Government continues to fund the 20%.

There exists also agreement between Federal and Laender governments that the Initiative for Excellence ('Exzellenzinitiative') will be extended beyond 2017¹⁹. Taking these pact extensions together, the Federal Government will increase its funding by €27b (NRP, 2015).

Other recent R&I policy initiatives include (see also section 2.3 of this report):

- BMBF has launched a new roadmap process for research infrastructure on 31 August 2015 with a submission deadline of January 2016²⁰. The process defines minimum investment costs (German share) as €50m per project (€20m in social sciences) (BMBF, 2015e). Selected projects enter the national roadmap for research infrastructures ('Nationale Roadmap Forschungsinfrastrukturen') with a timeframe until 2018.
- The Federal Government has announced a new research initiative titled "Kopernikus-Initiative" in September 2015²¹. The initiative is designed to support research in storage, transport and industrial usage of energy as well as the interaction between conventional and alternative sources of energy ('Kopernikus-Projekte für die Energiewende'). BMBF will provide €120m in funding until 2018 and additional €280m until 2025.
- The Federal Government has agreed in September 2015 to reform the act on temporary employment in science ('Wissenschaftszeitvertragsgesetz')²² which had been criticized for creating an undue number of short-term employment contracts for junior researchers and a barrier to career planning²³. The revised law ties the duration of the employment contract directly to the desired level of qualification, e.g. a PhD project, or third party grant ('Drittmittel') (see also section 4.4.1 of this report).
- The Federal Government has announced a new programme „Innovation for production, service and work for tomorrow" ('Innovationen für die Produktion, Dienstleistung und Arbeit von morgen') focusing on positive employment effects

¹⁶ <http://www.gwk-bonn.de/fileadmin/Papers/GWK-Heft-38-PFI-Monitoring-Bericht-2014.pdf> and <http://www.gwk-bonn.de/fileadmin/Papers/PFI-2011-2015.pdf> (9/2015)

¹⁷ <http://www.gwk-bonn.de/fileadmin/Papers/PFI-III-2016-2020.pdf> (9/2015)

¹⁸ <https://www.bmbf.de/de/dfg-programmpauschale-513.html> (1/2016)

¹⁹ <http://www.gwk-bonn.de/fileadmin/Papers/PFI-III-2016-2020.pdf> (9/2015)

²⁰ <http://www.bmbf.de/press/3845.php> (8/2015)

²¹ <http://www.bundesregierung.de/Content/DE/Artikel/2015/09/2015-09-17-kopernikus-wanka.html> (1/2016)

²² <https://www.bmbf.de/de/bessere-bedingungen-fuer-den-wissenschaftlichen-nachwuchs-1049.html> (1/2016)

²³ <http://www.gew.de/wissenschaft/wissenschaftszeitvertragsgesetz/> (9/2015)

from digital production and services. It has a budget of €1b until 2020 (BMBF, 2014f).

- BMBF has launched a platform Industry 4.0 ('Plattform Industrie 4.0') in April 2015²⁴. The platform organizes interdisciplinary expert groups with members from politics, business, science and unions. These expert groups will develop recommendations on Industry 4.0 relevant topics such as standardisation, research, security, legal frameworks, work, training and education.

Evaluations, consultations, foresight exercises

The most comprehensive evaluation at the system level of R&I in Germany is carried out by the Expert Commission on Research and Innovation (EFI). The Commission consists of six Professors who cover a broad field of expertise of R&I-related topics. The EFI commission publishes a comprehensive, annual report (available in German and English language versions). In its 2015 report EFI emphasizes particularly the following issues:

- Promoting innovation through cluster policy
The Expert Commission highlights best practices which should be adopted in future cluster policies such as multi-staged, technology-open competitions and evaluations modelled after the initial evaluation of the Federal Government's Leading-Edge Cluster Competition ('Spitzencluster-Wettbewerb'). The evaluation of the latter programme is recommended to be extended to medium and long term effects. Further the Commission envisions successful clusters as border-spanning (regional and national) as well as flexible and adaptive in exchange forms (e.g. encouraging collaborations between SMEs and large firms). The Commission advises against the extension of the Leading-Edge Cluster Competition beyond the third funding period because of expected decreasing effects.
- Massive Open Online Courses (MOOCs) as an innovator in the educational sector
The Commission recommends that all tertiary education institutions explore and experiment with the opportunities from MOOCs, e.g. for study admission. Some universities may be better off joining efforts. Government funds should be used for quality improvement through MOOCs but should not come at the expense of university education budgets.
- Digital innovation and the need for reform of copyright law
The Expert Commission recommends changes and simplifications in copyright laws. These include the permission of redesigns for non-commercial use to encourage user innovation as well as the introduction of violation alerts preceding the current practice of costly, formal warnings. Besides, the Commission recommends a general exemption of scientific findings from copyright laws to provide broad access. The exemption could be accompanied by compulsory compensation.
- Additive manufacturing ("3D printing")
The Expert Commissions recommends broad sets of support for additive manufacturing ranging from interdisciplinary research collaborations and technology transfer (nationally and internationally) to including relevant skills in vocational training programs. The Commission sees potential in strengthening the additive manufacturing components of Industry 4.0 initiative as part of the Digital Agenda and showcasing best practices. It also encourages the government to resolve legal issues such as liabilities, testing, standards or certifications.

As mentioned above, a consortium of two German research institutes, one German university and an Austrian research institute delivered the evaluation report of the first funding round of the Leading Edge Cluster Competition ('Begleitende Evaluierung des Förderinstruments „Spitzencluster-Wettbewerb“ des BMBF) (RWI, 2014). The

²⁴ <https://www.bmbf.de/presse/gemeinsame-plattform-industrie-4-0-startet-1017.html> (9/2015)

comprehensive report concludes that the policy is performing well along several dimensions such as the innovation performance (e.g. number or product innovations, patents, newly established collaborations) compared with national and international benchmarks. The evaluation report highlights the positive effects of exchanges between clusters in cluster-conferences or evaluation workshops. It recommends further that some clusters may require follow-up funding and a long-term effect ex-post evaluation.

The German Council of Science and Humanities ('Wissenschaftsrat') conducts evaluations and provides counselling for Federal and Laender governments. The council provides comprehensive reviews incorporating all system relevant aspects. A recent example is the "recommendations on the development of medical education in Germany based on a review model of medical degree programmes"²⁵.

Since 2007 the ministers and senators of the Federal Government and the Laender responsible for science and research as well as for finance form the Joint Science Conference (GWK). It provides annual monitoring reports and identifies room for improvement in projects such as annual monitoring of the policy initiative for improved funding of non-university research organisations ('Pakt für Forschung und Innovation') (GWK, 2015). GWK has commissioned an international expert commission ('Internationale Expertenkommission Exzellenzinitiative, IEKE') with the evaluation of the Initiative for Excellence²⁶. The commission reported final results in January 2016. The report concludes that the Initiative for Excellence had positive effects for R&I in many areas and recommends its extension with some adjustments (IEKE, 2016).

The most comprehensive foresight initiative is conducted by BMBF²⁷. The actual foresight project is conducted in a biannual cycle with a time horizon of 15 years into the future. The goal is to provide inputs and ideas about necessary needs of the German R&I system in the future as well as providing an early warning system for challenges. The current cycle (started in 2012) builds on the assumption that both technological opportunities and demand in society create innovations. The methodological approach has therefore been to investigate both streams (technology push and demand pull) separately before connecting them in a third stage. The final report was published in the end of 2014. The interim report capturing the societal demand aspect was published in August 2014. This interim report (BMBF, 2014e) titled "Societal Challenges 2030" ('Gesellschaftliche Herausforderungen 2030') lists seven fields ranging from citizen involvement in R&I to frictions between digital data transfers and privacy protection concerns. The final report titled "Stories from the future" ('Geschichten aus der Zukunft') describes nine narratives which are supposed to start and inspire new discussions about the future (VDI Technologiezentrum, 2015). The topics of the nine narratives are:

- Germany Selfmade ('Deutschland Selbermachen')
- Selfassessment and Wellbeing Competence ('Selbstbeobachtung und Wohlergehens-Kompetenz')
- Colleague Computer ('Arbeitskollege Computer')
- Education for Everybody and Everything ('Bildung für alle(s)')
- Act Locally – Collaborate Globally ('Lokal handeln – global kooperieren')
- Data intensive Government ('Datenintensive Governance')

2.3 European Semester 2014 and 2015

The National Reform Programme 2015 for Germany contains two quantitative goals (NRP, 2015):

- Germany should reach R&D expenditures totalling 3% of GDP with two-thirds stemming from business sectors. Germany comes close to reaching this goal with 2.84% in 2014, albeit the number is only slightly higher than 2013 (2.83%) and

²⁵ http://www.wissenschaftsrat.de/download/archiv/4017-14_Executive-Summary.pdf (8/2015)

²⁶ <http://www.ieke.info/ieke> (8/2015)

²⁷ <http://www.bmbf.de/de/24525.php> (8/2015)

lower than 2012 (2.87%). Business R&D expenditures (BERD) are consistently close to two thirds of total R&D expenditures (GERD), 69% in 2013.

- Germany has set a goal of 10% of its GDP being spent on research and education by 2015. Germany is close to the 10% goal with 9% of GDP spent on research and education in 2012 (NRP, 2015). While the absolute number is close to the 10% goal, the trend is diverging. Germany reported 9.5% in 2010 (NRP, 2013) and 9.3% in 2011 (NRP, 2014).

The country-specific recommendations for R&I of the European Commission reflect this gap between goal and goal achievement in response to the National Reform Programme (European Commission, 2015a). The recommendations ask for increased investments in research and education given the available fiscal space.

The main R&I related measures in NRP (2015) increase the investments in research and education:

- Federal and Laender governments have agreed in December 2014 to continue the Pact for Research and Innovation ('Pakt fuer Forschung und Innovation III') from 2016 till 2020. This implies an annual 3% increase in funding for the research organisations (Fraunhofer-Gesellschaft, Helmholtz-Gemeinschaft, Max-Planck-Gesellschaft, Leibniz-Gemeinschaft und Deutsche Forschungsgemeinschaft). The predictable increases provide the organisation with stable planning conditions. The Federal Government will provide the additional funding of this extension exclusively. Together with the extension of the initiative for excellence ('Exzellenzinitiative') the Federal Government will increase its funding by €27b.
- Federal and Laender governments have agreed in December 2014 to the Higher Education Pact 2020 with the goal to provide 760,000 new students (compared with 2005) with higher education. For this purpose the Federal Government will provide €9.9b and the Laender €9.4b. For the first time 10% of the funds are reserved for quality improvements increasing graduation rates. Part of the Higher Education Pact 2020 is also that universities will see an increase of their lump-sum allowance for indirect project costs ('DFG Programmpauschale') of grants from the German Science Foundation (DFG) from 20% to 22% starting in 2016²⁸. The Laender will cover the additional 2% while the Federal Government continues to fund the 20%.
- The Federal Government took over the financial responsibility for the student subsistence grants ('BAfoeG') beginning 2015. Laender are supposed to use the newly available budgets of €1.2b annually for funding higher education. Widened eligibility criteria and increased maximum amounts of grants will be implemented starting in the winter semester of 2016. The Federal Government has announced the new high-tech strategy ('Neue High-Tech Strategie) as an overarching R&I strategy (see also section 2.1 of this report) and the digital agenda 2014-2017 as the strategy for digital society and economy.
- The Federal Government has announced a new programme „Innovation for production, service and work for tomorrow“ ('Innovationen für die Produktion, Dienstleistung und Arbeit von morgen') focusing on positive employment effects from digital production and services. It has a budget of €1b over seven years (BMBF, 2014f).
- Several improvements in the support for entrepreneurship are enacted such as the improvement in the grant opportunities for entrepreneurship from science ('EXIST – Existengruendungen aus der Wissenschaft') or the tax exemption for government grants for business angels ('INVEST – Zuschuss fuer Wagniskapital').
- There have also been several improvements for attracting international students and skilled workers, such as information hotlines ('Make it in Germany', 'Arbeiten und Leben in Deutschland') as well as simplification in the accreditation of diploma from abroad.

²⁸ <https://www.bmbf.de/de/dfg-programmpauschale-513.html> (1/2016)

- NRP (2015) is largely an extension of NRP (2014) which had the following main components:
- Increase investment on education and research
- Continue the three central R&I policy initiatives: 'Exzellenzinitiative', 'Hochschulpakt' and 'Pakt für Forschung und Innovation'
- Develop new key areas for innovation support: Big data and health care prevention
- Strengthen technology transfer between academia and business
- Reduce funding constraints for start-up and young firms
- Enact a digital agenda involving broadband internet, ICT technology and security
- Intensify ERA and develop it actively.

In sum, the measures outlined in NRP (2015) and NRP (2014) reflect the R&I challenges identified by the European Commission in its 2015 European Semester Country Report (European Commission, 2015b). The Expert Commission on Research and Innovation (EFI) questions whether the goals are ambitious enough or whether Germany should for example strive for a goal of 3.5% of GDP spent on R&D (EFI, 2015).

2.4 National and Regional R&I Strategies on Smart Specialisation

Smart specialisation builds on the concept of regional innovation systems (RIS) in which innovation performance is not exclusively determined by individual actors such as firms or universities in isolation but also by their interactions. The smart specialisation concept takes into account that not a single best practice for such RIS exists but that regions can develop individual strategies tailored to their needs and opportunities.

Smart specialisation is part of the agreement between Germany and the European Commission on the implementation of the European Structure and Investment fund²⁹ and at least implicitly part of Germany's new High Tech Strategy 2020 (BMBF, 2014d) and explicitly part of the National Reform Programme (NRP, 2015). In this regard, Germany has several policy initiatives to leverage geographical clusters such as the Leading-Edge Cluster Competition ('Spitzencluster-Wettbewerb') of BMBF with a budget of €200m for up to five leading edge Clusters in each round of funding (BMBF, 2015d). However, there is currently no policy document which explicitly outlines a smart specialisation strategy at the federal level. This is largely due to the federal structure of Germany in which the Laender have important authority over R&I. There is some indication that the Federal Government prioritizes strengthening the international connectedness of the Leading-Edge Clusters. Examples include the successful application for two Knowledge and Innovation Communities (KIC) ("Raw materials" and "Healthy living and active aging") in a European-wide competition of the European Institute of Technology which will be coordinated in Germany (BMBF, 2014a). Support for the internationalisation of Leading-Edge Clusters, Future Projects and comparable networks ('Internationalisierung von Spitzenclustern, Zukunftsprojekten und vergleichbaren Netzwerken') is now a BMBF programme with three yearly funding rounds between 2015 and 2017. In each round cluster or network managements can apply for funding for the development of internationalisation concepts (up to two years) and implementation (up to three years).³⁰

The Laender have been going through the process of developing smart specialisation strategies. These efforts are largely part of developing RIS3 strategies as a prerequisite for applying for funds from the European Regional Development Fund (ERDF). Hessen, for example, engaged in a socio-economic analysis of strengths, weaknesses, opportunities and risks in 2013 (HA Hessen Agentur, 2013). The analysis had the explicit

²⁹ <http://www.bmwi.de/BMWi/Redaktion/PDF/P-R/partnerschaftsvereinbarung-zwischen-deutschland-und-der-eu-kommission-fuer-die-umsetzung-der-esi-fonds-unter-dem-gemeinsamen-strategischen-rahmen-in-der-foerderperiode-2014-2020-teil-1.property=pdf.bereich=bmwi2012.sprache=de.rwb=true.pdf> (1/2016)

³⁰ <http://www.bmbf.de/de/25370.php> (8/2015)

goal to provide input for setting priorities in programmes such as ERDF. Some Laender, such as Saxony³¹ or Schleswig-Holstein publish dedicated regional innovation strategies (Schleswig-Holstein Ministry for Economics Labour Traffic and Technology, 2014). Most Laender have published regional innovation strategies as part of their operational programmes for ERDF, such as Hessen (Hessen Ministry for Economics Energy Traffic and State Development, 2014), Baden-Württemberg (Baden-Württemberg Ministry for Rural Areas and Consumer Protection, 2014) or Brandenburg (Brandenburg Ministry for Economics and Energy, 2014).

By design, RIS3 strategies of Laender differ but all discuss complementarities in funding and effects with other instruments at the federal or European level. Naturally, the RIS3 strategies in the operational programmes have detailed financial considerations both in terms of total requirements and the share of EU contribution. Baden-Württemberg, for example, has a detailed financial plan separating EU and national contributions wherein the latter are further broken down into federal public and private funds (Baden-Württemberg Ministry for Rural Areas and Consumer Protection, 2014). Other Laender, such as Brandenburg (Land Brandenburg Ministry for Economics and Energy, 2014) or Hessen (Hessen Ministry for Economics Energy Traffic and State Development, 2014) treat private contributions largely as output indicators particularly in the form of private R&D investments. Some Laender, such as Saarland³², include R&I infrastructure investments at universities or research organisations in their RIS strategies but it is not necessarily a common feature.

Measures to stimulate private investment are part of communication strategies such as in Bavaria³³. Many stimulation instruments are directed at providing information about grant opportunities. These can be digital in nature, e.g. for the city-state Berlin³⁴ or involve presentations at institutions like the chamber of commerce, e.g. in Saarland.³⁵

Monitoring and evaluation is part of the regional strategies. They follow the lines of appropriate monitoring within RIS3 (JRC, 2015). Relevant input indicators are correlated with evidence-based outcomes in pre-defined monitoring periods. Schleswig-Holstein, for example, includes a structured model of strategic controlling in its RIS strategy which combines quantitative changes, e.g. patent intensities or new cluster memberships, with qualitative analysis, e.g. expert interviews (Schleswig-Holstein Ministry for Economics Labour Traffic and Technology, 2014). This particular monitoring process contains also the final step of a strategic controlling process, i.e. the strategy review and optimisation. All Laender monitoring approaches, such as in Baden-Württemberg in December 2014 involve review councils ('EFRE-Begleitausschusses') consisting of stakeholders from various groups of society (e.g. business, academia, regions, municipalities).³⁶

In sum, smart regionalisation strategies have been adopted earlier in some Laender, e.g. Saxony, than in others. Nevertheless, the requirements of European Regional Development Fund (ERDF) have led in all Laender to an active discussion of regional strategies and priorities. All German program applications to EFRE and ESF have been approved for the period 2014-2020³⁷. Most of the resulting regional strategies leverage existing regional strengths instead of replacing them. There is consensus as well as diversity between Laender in their regional innovation strategies. This can be seen as an indication for a more tailored and hence smarter strategy process. BMWi provides an

³¹ <http://www.innovationsstrategie.sachsen.de/en/smart-specialisation.html> (8/2015)

³² http://www.saarland.de/dokumente/thema_strukturfondsfoerderung/PPP07052015.pdf (8/2015)

³³ http://www.efre-bayern.de/fileadmin/user_upload/efre/dokumente/Kommunikationsstrategie_Stand_April_2015.pdf (8/2015)

³⁴ <http://www.berlin.de/sen/wirtschaft/gruenden-und-foerdern/europaeische-strukturfonds/efre/informationen-zur-beantragung/beantragung-im-rahmen-des-ops-2014-2020/> (8/2015)

³⁵ http://www.saarland.de/dokumente/thema_strukturfondsfoerderung/PPP07052015.pdf (1/2016)

³⁶ <http://www.efre-bw.de/pressemitteilung/begleitausschuss-fuer-das-efre-programm-baden-wuerttemberg-2014-2020-trifft-sich-zu-ersten-sitzung/> (8/2015)

³⁷ http://ec.europa.eu/deutschland/press/pr_releases/13085_de.htm (1/2016)

overview on EFRE and ESF conditions as well as project examples³⁸. Otherwise there is no information platform available that would allow the comparison or progress tracking of Laender regionalisation strategies.

2.5 Main policy changes in the last five years

Main Changes in 2011

Decision on new energy policy excluding nuclear power
Introduction of "High-tech Start-up Fund II"
Introduction of "blue card" for simplified work permission for foreigners in Germany

Main changes in 2012

Freedom of Science law ('Wissenschaftsfreiheitsgesetz') goes into effect
Funding from third round of Initiative for Excellence begins
Foreign Skills Recognition law goes into effect

Main changes in 2013

Election of Federal Parliament
Establishment of the competence centre for public procurement
National research infrastructure roadmap (i.e. for instance large scale research infrastructures of national / European importance, comprehensive experiments, etc.).

Main Changes in 2014

New Federal Government collation began its work
Agreement on extension of the pacts and change in constitution by federal and Laender governments
Renewal of the High Tech Strategy of the Federal Government

Main Changes in 2015

Constitutional amendment to allow permanent funding of universities through agreements between federal and Laender governments
Extension and refinement of Pact for Research and Innovation ('Pakt für Forschung und Innovation') and Higher Education Pact ('Hochschulpakt') until 2020
Reform the law for temporary employment in science ('Wissenschaftszeitvertragsgesetz')

³⁸ <http://www.bmwi.de/DE/Themen/Europa/Strukturfonds/bund-laender.html> (1/2016)

3. Public and private funding of R&I and expenditure

3.1 Introduction

Total R&D expenditures in Germany have reached 2.88% of GDP in 2014 which is slightly higher compared with 2013 (2.83%) but significantly above the average of EU-28 of 2.03%. R&D expenditures in Germany have increased consistently over the last four years with total R&D appropriations (GBAORD) reaching €25.4b in 2014, an increase of 6.83% compared with 2011 (see Table 2 for details).

Private businesses consistently account for two-thirds of R&D spending in Germany. As a percentage of GDP, business R&D expenditures account for 1.95% of GDP in 2014 which is a slightly higher compared with 1.9% in 2013. The 2015 EU Industrial R&D Investment Scoreboard provides an overview on the distribution of the 2,500 firms with the largest R&D investments worldwide. 136 of these firms are headquartered in Germany. The German automotive firm Volkswagen is the worldwide number one of all firms with R&D investments reaching €13.1b or 6% of sales in 2014. Other large R&D investing firms headquartered in Germany among the top 50 worldwide include Daimler (14th spot), BMW (21), Robert Bosch (17), Siemens (24), Bayer (29), Boehringer Ingelheim (44) and SAP (50). In general, Germany benefits from a strong base of R&D investment from firms in medium high-tech manufacturing sectors, like automotive production, chemicals as well as machinery and equipment. In particular firms in the automotive sector in Germany play an important role. They account for three quarters of R&D investment in this sector in Europe and have increased their R&D investments by 9.7% in 2013 (European Commission, 2014c). In more general terms, firms on the R&D investment scoreboard headquartered in Germany have increased their R&D spending by 5.8% in 2013, compared with a worldwide increase of 4.9% and 2.5% of all EU headquartered firms.

A noteworthy pattern within these positive numbers of business R&D spending in Germany is identified by the Expert Commission on Research and Innovation (EFI) in its 2015 annual report (EFI, 2015). EFI finds that spending on innovation by small and medium sized firms ('Mittelstand') is decreasing. While the report asks for more research to identify drivers behind this observation, it deserves particular attention in the German context. Small and medium sized firms (SMEs) are particularly central to the German economy. SMEs are the most important source for employment and value added in Germany, more important than in any other European country and this importance has grown in recent years (European Commission, 2014a).

The Federal Government has provided €14.9b for R&D in 2015, an increase of €261m compared with 2014.³⁹ The budget plan for 2016 foresees another significant increase with a planned total budget for R&D of €16.4b (Deutscher Bundestag, 2015b). The Laender themselves are important funding bodies for research and education. They have invested €10.2b in R&D in 2012 which is an increase of 5.2% compared with 2010 levels (BMBF, 2014c). Laender investments in R&D are substantial and amount to roughly 75% of the investments of the Federal Government. Laender budgets for R&I are expected to be stable or grow slowly (BMBF, 2014c). There is a noticeable trend for the Federal Government to assume more financial responsibility for funding R&I in Germany. Examples include budget increases originating from the extension of the Pact for Research and Innovation and the decision of the Federal Government to take over funding for the student subsistence grants ('BAfoeG') from the Laender beginning 2015 (NRP, 2015). Laender are supposed to use the newly available budgets from the latter of €1.2b annually for funding higher education. Similarly, the programme allowance for indirect project costs ('DFG Programmpauschale') of grants from the German Research Foundation (DFG) as part of the Higher Education Pact 2020 will comprise 22% of

³⁹ <https://www.bmbf.de/presse/rekordinvestitionen-in-innovationen-115.html> (9/2015)

project grants starting in 2016.⁴⁰ The Laender will cover 2% while the Federal Government funds 20%.

Germany has received a total €4.02b for projects related to Research, Technology and Development (RTD) as part of the EU Structural Funds between 2007 and 2012 (RIO elaboration on DG Regio data)⁴¹. This is a strong increase compared to the total receipts of €2.2b for RTD in Germany between 2000 and 2006. It should be noted that data refer to allocated funds and not to the real execution.

Focussing on the participation in EU framework programmes, Germany received 4,388 projects from the FP6 programme with €3.02b in funding. That equals 19.2% of all EU funds allocated in FP6. By comparison, Germany received only 17.6% of EU funds from FP7, with 8,897 projects and €7.2b in funding. Success rates of applications from Germany are above average (24%) compared to the EU average of 20.4% (European Commission, 2014b). In absolute terms, Germany is the largest recipient of FP7 but as a percentage of GDP its share is below EU average. Characteristic for FP7 projects from Germany is that a high share of projects involves the private sector (33%) (BMBF, 2014a). Within Horizon 2020 Germany seems well positioned to increase its share of funding with a current funding level of 20.3% of total EU funds.

Table 2 Basic indicators for R&D investments

Indicator	2011	2012	2013	2014	EU average (2014)
GERD (as % of GDP)	2.79	2.87	2.88	2.84	2.03
GERD (Euro per capita)	923.5	966.6	972.1	1,038	560
GBAORD (€m)	23,743.525	24,070.224	25,370.994	25,363.5	93,629.532 (EU-28 total)
GERD funded by BES (% of GDP)	1.83	1.90	1.85	n.a.	1.12 (2013)
GERD funded by PNP (% of GDP)	0.01	0.01	0.01	n.a.	0.03 (2013)
GERD funded by GOV + HES (% of GDP)	0.83	0.84	0.82	n.a.	0.68 (2013)
GERD funded from abroad (% of GDP)	0.12	0.12	0.15	n.a.	0.20 (2013)
GERD performed by HEIs (% of GDP)	0.50	0.51	0.51	0.49	0.47
GERD performed by government sector (% of GDP)	0.41	0.41	0.42	0.43	0.25
R&D performed by business sector (% of GDP)	1.89	1.95	1.90	1.95	1.30

Note: Data for 2014 is based on estimates.

⁴⁰ <https://www.bmbf.de/de/dfg-programmpauschale-513.html> (1/2016)

⁴¹ The data on structural funds (RIO elaboration of DG REGIO data) is low in comparison to data reported elsewhere such as last year's country report. One of the explanations for this difference is the definition adopted. The data presented here refers to Core RTD (See Annex for categories included), whereas the information provided elsewhere adopts a broader definition of RTDI and linked activities. In addition the data reported here refers to ERDF funding only and does not include cohesion funds.

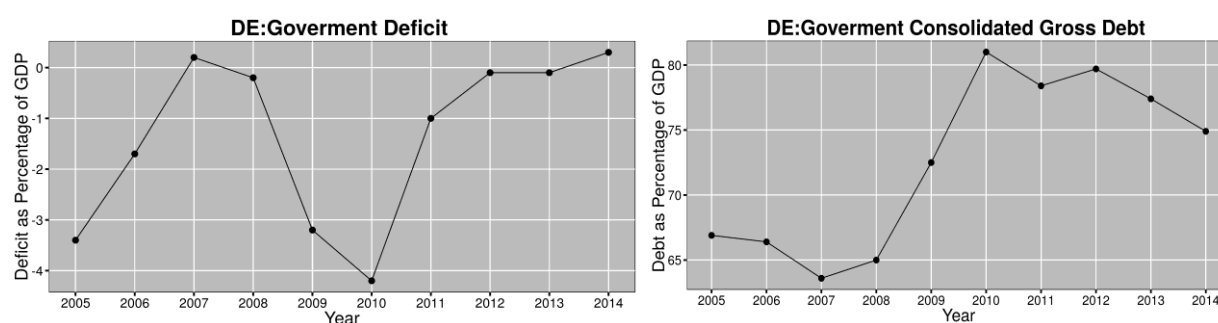
3.2 Smart fiscal consolidation

3.2.1 Economic growth, fiscal context⁴² and public R&D

Real GDP in Germany rose by 1.6% in 2014 and 1.7% in 2015 and it was driven mainly by domestic demand. Since 2012 domestic demand has been the main contributor to GDP growth and is expected to remain so in the coming years. In 2014 its largest component was private consumption. The Commission expects further strengthening of the economic activity due to the strong labour market, favourable financing conditions, falling oil prices and improving external environment. Real GDP is expected to increase by 1.8% in both 2016 and 2017.

Before the crisis Germany had an improving budgetary balance. The deficit decreased gradually and turned into surplus by 2007 (Figure 2). The crisis had a negative impact on the German economy with an immediate consequence of widening budget deficit and increasing public debt between 2008 and 2010. Given that the impact of the crisis was not very strong (i.e. the GDP fell only in 2009 and only by ca. 5.5%, succeeded immediately by rather robust growth), public finances stayed under control both in terms of deficit and debt. Both the federal and the Laender governments have committed themselves to balanced budgets ('Schuldenbremse'). Laender differ in their progress towards balanced budgets but overall Germany had almost balanced budgets in 2012 and 2013 (-0.1% of GDP) and a surplus in 2014 (0.3% of GDP) and 2015 (0.5% of GDP). Equilibrated budgets are projected for 2016-17. The debt-to-GDP ratio is expected to fall steadily from the actual level of 74.9% to 66.8% by the end of 2017.

Figure 2: Government deficit and public debt



Data source: Eurostat

Total GERD in Germany was €79,730m in 2013. There are three main sources of R&D funding: the business sector (€52,176m), the government (€23,198m), and foreign funding (€4,110m). Direct funding from the government goes to R&D institutes in the business enterprises (€1,800m), the government (€9,864m) and the higher education sector (€11,534m).

Table 3: Key German Public R&D Indicators

	2007	2009	2013
GBAORD, % of gov. exp.	1.70	1.82	2.01
GERD, % of GDP	2.45	2.72	2.83
out of which GERD to public, % of GDP	0.73	0.88	0.93
Funding from GOV to, % of GDP			
Business	0.08	0.08	0.06
Public (GOV+HES)	0.60	0.73	0.76
Total	0.67	0.81	0.82
EU funding, % of GDP * **	n.a.	n.a.	0.05

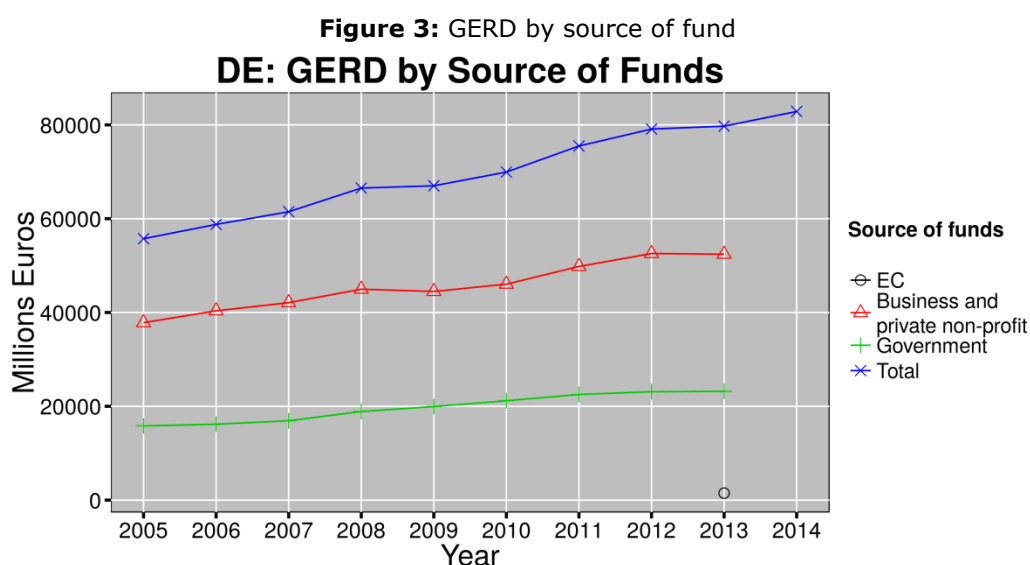
Source: Eurostat

⁴² Sources: DG ECFIN, http://ec.europa.eu/europe2020/pdf/csr2016/cr2016_germany_en.pdf

3.2.2 Direct funding of R&D activities⁴³

Figure 3, below shows the historical evolution of GERD financing in current prices in Germany. The private sector plays a leading role in the financing of the GERD in Germany, which amounts to more than twice the contribution from the government. They both grow almost linearly in the period from 2005 to 2013 for which data are available (with the exception of a minor dip in the business contribution in 2009). From 2010 onward, the private sector shows greater vitality than the government in funding the German GERD as can be seen from the steeper increase in the contribution from the former.

Unfortunately, German official statistics provide quantitative data about the EC contribution to the financing of the GERD only for 2013 which corresponds to approx. 5% of the total GERD and 0.05% of GDP. Assuming that this share hasn't changed much over the years it is safe to conclude that EC contributions are small with respect to the contributions from the government and the private sector.

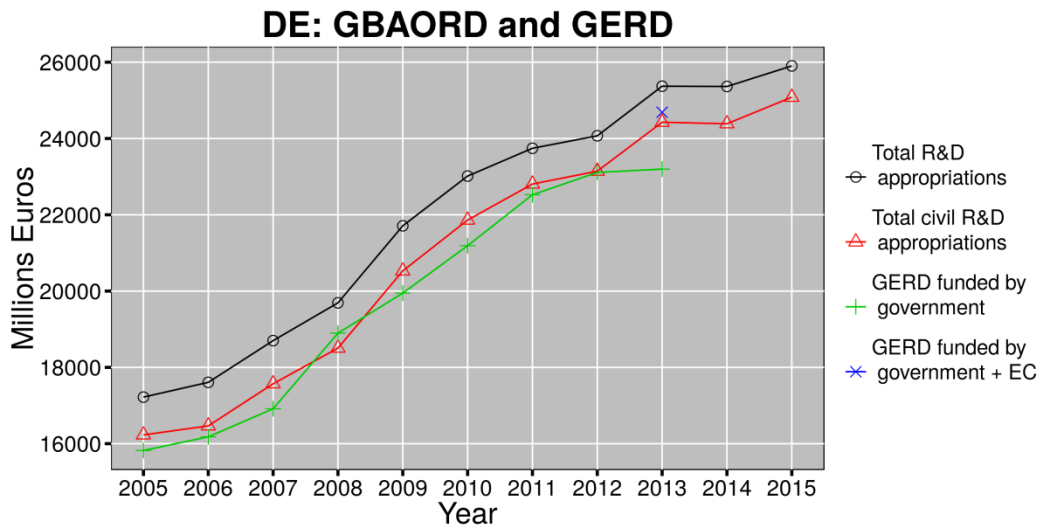


3.2.2.1 Direct public funding from the government

The total (civil) appropriations (GBAORD) have been following a growing trend from 2005 onwards. The difference between total and total civil appropriations measures the military R&D appropriations and is approximately constant in the period under scrutiny. The GERD funded by the government behaves similarly to the total civil appropriations. Until 2012 the civil appropriations and the government funded GERD are very close but in 2013 the GBAORD increases whereas the government funded GERD remains at the level of 2012. However, when adding EC funding the total direct public support reaches (and even surpasses) the total civil R&D appropriations.

⁴³ The sources of R&D funding according to the Frascati manual are: Government sector (GOV), Higher education sector (HES), Private non-profit sector (PNP) and Abroad (including EC). In this analysis the public sector as source of funds is given by the GOV part of the total intramural R&D expenditure (GERD), whereas the public sector as a sector of performance is the aggregation of GOV and HES.

Figure 4: total (civil) appropriations and GERD funded by the government



3.2.2.2 Direct public funding from abroad

Unfortunately, little data is available about the public direct funding from abroad, as one can see in the table below:

Table 4: External public sources used for financing total German R&D

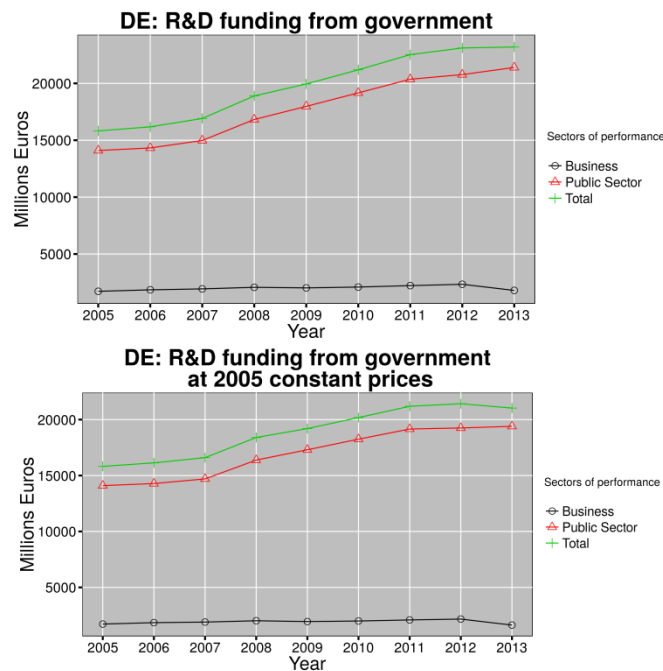
Source from abroad	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total	2088.59	2246.10	2468.16	2669.72	2577.12	2716.46	3158.13	3420.33	4109.78
BES									2156.90
EC									1490.06
International Organizations									70.17
Total as % GERD	3.75	3.82	4.01	4.01	3.85	3.88	4.18	4.32	5.15
EC as % GOVERD									6.42

The funding from abroad, overall, has increased from less than 4% to above 5% of the total GERD the period 2005 – 2013. Based on 2013 data, R&D financing from Abroad corresponds to 5% of the total GERD of which about 52% comes from the foreign Business sector and about 36% comes from the EC through Structural Funds and Framework Programmes.

Distribution of public funding

Figure 5, below shows how the distribution of public funding to sectors of performance evolved over time:

Figure 5: Government intramural expenditure by sectors of performance



Data source: Eurostat

Unsurprisingly the public sector (GOV+HES) is the main recipient of the government funding. The funding received by the public sector increased almost linearly in the period 2007-2013. The trend is essentially the same also when measured at 2005 constant prices. Interestingly, in 2013 the direct public support to businesses, which is already low, decreases further whereas the support to the public sector keeps increasing (or remains unchanged when measured in constant prices).

3.2.3 Indirect funding – tax incentives and foregone tax revenues

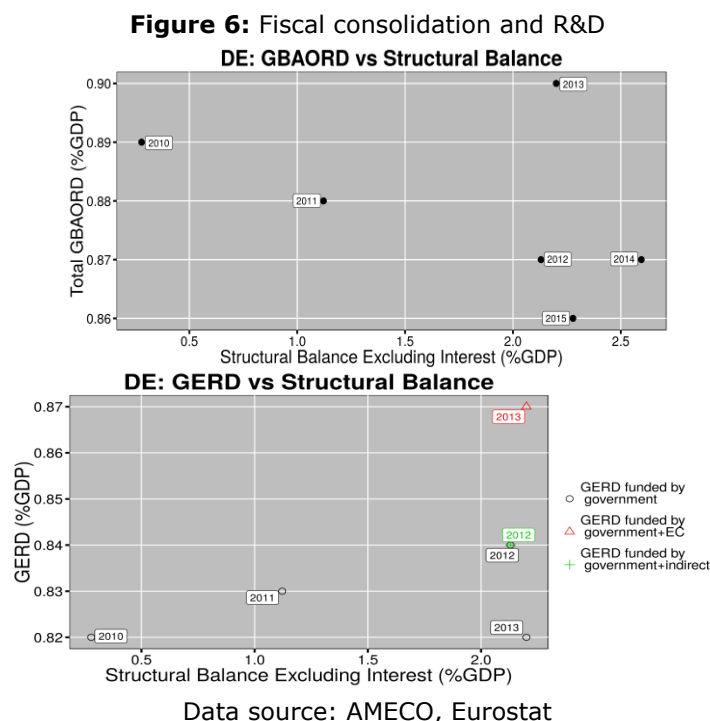
Germany is the only big EU country whose R&I funding system does not include any tax credits. Instead, R&D funding in Germany takes the form of direct funding schemes on both federal and state levels (non-repayable cash grants, loans and participation programmes among which the Central Innovation Program for SMEs^{II} (ZIM) may be the best known) (European Commission, 2014e).

The introduction of R&D tax credits has on several occasions been recommended to the German government by the Expert Commission on Research and Innovation (EFI) and had also been enshrined in the last Federal Government's coalition agreement (2009 – 2013). However, under the current government political momentum for the introduction of tax credits has decreased and the item moved down on the political agenda of priorities. The potential fiscal costs of introducing preferential tax treatment for R&D in the Germany system have also been debated but there are only few concrete estimates. The Centre for European Economic Research (ZEW) estimates the fiscal costs of support in the form of a hypothetical tax credit on R&D expenses between €464m and €5,701m (European Commission, 2014e).

In spite of the lack of tax incentives, Germany has a R&D intensive industry and many internationalised companies that are often technology leaders in their sectors are headquartered in Germany. The same applies for countries like Finland and Switzerland which do not offer preferential tax treatment for R&D either.

3.2.4 Fiscal consolidation and R&D

Although the headline deficit of the country had to be diminished, in structural terms the German budget had a surplus throughout the whole post-crisis period. Figure 6, below shows the scatterplot of the structural balance and a relevant measure of the R&D (GBAORD as % GDP, first panel and GERD as % GDP, second panel)⁴⁴:



Based on the graphs, at first glance the picture is mixed: while GBAORD as % of GDP is decreasing, government GERD is increasing steadily during the same period, although neither of the two faced a nominal decrease. The reason behind is that the growth rate of government GERD was higher than that of the GDP, which in turn outpaced the slightly lower growth of GBAORD. However, in order of magnitude the post-crisis changes in GBAORD and government GERD in terms of GDP are very low (0.02% of GDP). Indeed, when measured as percentage of GDP, both the German GBAORD and the government funded GERD register fluctuations which are about an order of magnitude smaller than those experienced by the same indicators in France, Italy or the United Kingdom. Based on the above discussion it seems that the German post-crisis fiscal consolidation process has not come at the expense of public R&D expenditures.

The German economy consolidated in the years after the crises. In particular, the years 2010-2011 saw high growth rates of the GDP and public finance consolidation in the form of reduction of the government deficit and debt. During the consolidation phase, despite some minor fluctuations, the fraction of GDP devoted to the public funding of R&D in Germany has been essentially preserved.

The European Commission recommends in its response to the National Reform Programme (European Commission, 2015a) the use of the available fiscal potentials for increased investments in research and education (see also section 2.3 of this report).

⁴⁴ Structural balance data comes from the AMECO database the other indicators were taken from Eurostat.

3.3 Funding flows

3.3.1 Research funders

The legal basis for the allocation of public funds for R&D is the 'Freedom for Science'-Article 5(3) of the German constitution ('Grundgesetz,' GG). Further, rules for joint funding by federal and state governments are laid out in Article 91b GG of the constitution and in the Federal Budget Code ('Bundeshaushaltsordnung,' BHO). Article 91b GG of the constitution has been changed based on votes of both chambers of parliament in December 2014 (Deutscher Bundestag, 2014). This change enables the Federal Government to be permanently involved in the funding of universities.

At the national level, the Federal Ministry of Education and Research (BMBF) covers most of the responsibilities for research policy. The Federal Ministry of Economics and Energy (BMWi) is also involved in some areas of innovation and technology policy. The Laender fund the universities in their state and co-fund Max Planck Society, Fraunhofer Society, Helmholtz Association, and Leibniz Association. The Laender also play a very active role in facilitating knowledge transfers between science and industry as well as other innovation programmes (see also section 1.2.2 of this report).

Apart from the main research organisations, there exist research institutes which provide ministries with specifically relevant scientific knowledge or assess quality or safety standards. ('Ressortforschungseinrichtungen'). Their budgets are comparatively smaller. R&D budgets of these institutes reached €965m or 7.2% of R&D funding of the Federal Government in 2013 (BMBF, 2014c). They are planned to reach €971m in 2014.

With regards to funding for basic research in Germany, the German Research Foundation ('Deutsche Forschungsgemeinschaft,' DFG) is crucial. It complements institutional funding with project funding. DFG selects the most promising research projects by scientists and academics at universities and non-university research institutions based on a competitive basis. Funding is typically the result of a bottom-up process of peer review. The review process is sophisticated and multi-layered:⁴⁵ The DFG head office appoints peer reviewers with relevant expertise (roughly 15,000 annually) while avoiding conflicts of interest. The reviewers evaluate academic excellence, relevance and originality of the proposals. The so-called review board, members of which are selected from the scientific community, evaluates and compares the reviews for selection of the most promising proposals (DFG, 2015a). The review process is international. Almost a third of all reviewers work outside Germany with the largest group working in the US (8.8%) (DFG, 2012).

R&D programmes put forward by ministries are administered and managed by various agencies with a clear coordination and implementation purpose ('Projektträger'). The latter are mostly located in large research centres.

Apart from these, several public and private foundations exist for financing research. The share of R&D financed by private, non-profit organisations is comparatively low at 0.01% of GDP in Germany in 2012. Examples for such foundations include the Volkswagen Stiftung, Fritz Thyssen Foundation, Alexander von Humboldt Foundation (AvH), or the Federal Foundation for the Environment. Additionally, R&D is also performed in the higher education sector through a combination of institutional funding and project funding (e.g. Initiative of Excellence, R&D thematic programmes by BMBF) and contract research conducted for industry. Aschhoff (2013) provides a detailed overview on German R&I system.

⁴⁵ http://www.dfg.de/foerderung/antragstellung_begutachtung_entscheidung_gutachtende/index.html (12/2014)

3.3.2 Funding sources and funding flows

The share of overall funding for R&D on government budgets has been stable at 3% from 2009 to 2012 (BMBF, 2015c). The Federal Government has increased funding for R&D from €9.0b in 2009 to €12.8b in 2010, €13.3b in 2011 and €13.5b in 2012 (BMBF, 2014c). This trend is supposed to continue. The budget plan for 2016 foresees another significant increase with a planned total budget for R&D of €16.4b (Deutscher Bundestag, 2015b). In contrast, the Laender have increased their funding for R&D continuously but with significantly lower growth rate from €9.3b in 2009, to €9.7b in 2010 and €10.2b in 2011 (BMBF, 2014c). Hence, in relative terms the Federal Government has become the most important funding source for R&D in Germany.

Funding for R&D from abroad is substantial but significantly lower. Total R&D funded from abroad account for 0.12% of GDP in Germany in both 2011 and 2012 (see section 3.1 Table 2 for details). BMBF (2014c) reports an average annual funding of €866m for R&D from the European Union between 2007 and 2013 because tranches of Seventh Framework Programme (FP7) projects are paid out sequentially. An individual annual number would therefore necessarily be unreliable. In total, Germany received funding of €7.2b for project within FP7 which as a significant increase compared with the €3.02b from the Sixth Framework Programme (FP6) (European Commission, 2014b).

In terms of EU structural funds related to Research, Technology and Development (RTD), Germany has received a total €4.02b between 2007 and 2012 (RIO elaboration on DG Regio data).⁴⁶ This is almost double the amount of €2.2b for RTD in Germany between 2000 and 2006. The Laender have used structural funds in various ways. Examples include (BMBF, 2014c):

- Lower Saxony initiated graduate schools which combine structural PhD training with labour market relevant competences. This is accompanied with an outreach initiative to regional business in order to facilitate hiring of highly qualified employees ('Wissenstransfer über Köpfe').
- Saxony has funded the construction and equipment of applied research institutes.
- Mecklenburg-Vorpommern has funded research collaborations in the fields of plasma physics and biotechnology.

Focussing on the absorption of funding by firms, the results of the Community Innovation Survey (CIS) provides firm level information (ZEW, 2014). 23.7% of all innovative firms⁴⁷ in Germany have received some kind of public support for their R&D or innovation activities between 2010 and 2012. This number is up from 19% in the timeframe 2006 to 2008 (CIS2008). 17.1% of innovative firms received funding from the Federal Government between 2010 and 2012. This share has more than doubled compared to the timeframe 2006 to 2008 (8%). EU funding has reached 5.2% of German innovative firms between 2010 and 2012, 3.7% benefitted from the 6th or 7th Framework Programme. Innovation support from the Laender and local authorities is still important with 7.4% of innovative firms receiving it but this share is down from 9% in the 2006 to 2008 period. In sum, there are many positive signals for R&I government funds reaching German companies and the trend is positive especially for funding from the Federal Government.

With regard to absorption rates of EU funding, there is no consensus on what an optimal rate would be. The success rate of grant applications from Germany in FP7 (24%) is higher than EU-average (20.4%) (European Commission, 2014b). FP7 project

⁴⁶ The data on structural funds (RIO elaboration of DG REGIO data) is low in comparison to data reported elsewhere such as last year's country report. One of the explanations for this difference is the definition adopted. The data presented here refers to Core RTD (See Annex for categories included), whereas the information provided elsewhere adopts a broader definition of RTDI and linked activities. In addition the data reported here refers to ERDF funding only and does not include cohesion funds.

⁴⁷ Information from the survey is limited to firms with technological activities, i.e. firms which invested into some form of R&D or innovation activities.

applications from Germany are also more likely to involve the private sector (33%) (BMBF, 2014a). Then again, compared to its share of GDP, Germany receives less FP7 funds than EU average. There is no precise estimate for the absorption capacity of Germany, i.e. the extent to which a country is capable of effectively and efficiently spending its Structural Funds allocation. Nevertheless, there are no obvious indications that Germany has reached the limits of its absorption capacity.

The importance of R&D expenditures from foreign controlled firms has increased in Germany between 1997 and 2007 but is at a moderate level with 26.2% of business R&D expenditures stemming from foreign-controlled affiliates (OECD, 2010). This level is significantly lower compared with Ireland (72.4%), Israel (61.8%) or Belgium (59.4%) but above countries such as Finland (17%), Switzerland (14.4%), the US (14.3%) or Japan (4.7%).

3.4 Public funding for public R&I

3.4.1 Project vs. institutional allocation of public funding

Public funding for R&D has two primary components in Germany: institutional (block) funding and project funding. Long-term institutional funding covers essential financial demands (basic facilities) of universities (Laender) and non-university research organisations (Federal Government and Laender governments). In contrast, project funding is directed at a particular goal with typically short to medium-term time horizons (Sofka, 2015). The German funding system is rather complex and precise shares of project vs. institutional funding of R&D are difficult to state reliably. EUROSTAT data shows that 37.2% of R&D funding is competitively allocated while 63.7% stem from institutional funding. These shares are hardly changing compared with 2011 and 2012. Then again, the "Joint and Open Research Programs in Germany" report (JOREP, 2011) suggests that funding schemes have shifted from institutional to project funding.

Public R&I in Germany is conducted in universities and the main non-university research organisations Max Planck Society (MPG), Fraunhofer Society (FhG), Helmholtz Association (HGF), and Leibniz Association (WGL). 1,125 employees of the research organisations had co-appointments as university professors in 2014 (2010: 745) (GWK, 2015).

Universities receive institutional funds ('laufende Grundmittel') for both teaching and research. These funds are largely provided by the Laender. These institutional funds amounted to €17.5b in 2012 or 43.4% of university income (DFG, 2015a). 16.8% (€6.8b) stem from competitive project funding ('Drittmittel') and 39.8% (€16b) from other income such as student payments or university hospitals (DFG, 2015a). Universities have comparatively higher shares of competitive project funding (17.9%) compared with universities of applied sciences (9.7%) or pedagogical, theological, art or music universities (5.5%). The ratio of competitively (performance based) to non-competitively (block funding) allocated funds has reached 28% in 2013 compared with 19% in 2003 (GWK, 2015). Hence, the importance of competitive funds is increasing over time.

The German Research Foundation DFG and the other main non-university research organisations are funded jointly by the Federal Government and the Laender governments. Those institutions had a total budget of €12.1b in 2014 with €7.9b stemming from institutional funds (65%) and €4.2b (35%) originating from competitive funding ('Drittmittel') (DFG is a funding organisation in itself) (GWK, 2015). Total budgets have increased by 6.7% compared with 2013 with institutional funds increasing by 6.1% and competitive funds by 7.9% following a similar pattern in the increases between 2012 and 2013 (GWK, 2015). These trends provide additional evidence that the importance of competitive funds for public R&I in Germany has been increasing.

3.4.2 Institutional funding⁴⁸

The funding of education and research at universities is devolved to a large extent to the sixteen states (Laender) which are highly autonomous in matters of education policy. In summary, the Laender's public funding typically consist of three possible procedures one of which is an incremental/discretionary/non-competitive part which is mainly based on the previous' year funding and corrected for inflation. During the past years, this approach to funding has gradually become less important. In order to achieve goals of the state government, like internationalisation and gender equality, the state government can financially award well-performing institutions. This type of funding is generally non-competitive (Van Daalen et al, 2014 as quoted in Jonkers & Zacharewicz, 2015.).

During the past decade, many Laender have introduced an indicator-based formula to determine the amount of public funding. Van Dalen et al. (2014) provide an overview of how formula based funding developed in 9 Laender over time. They observe an increase over time in the number of Laender that integrate an indicator-based formula into their funding program. Moreover, the individual shares increased as well for most Laender. This indicator-based part of the annual budget consists of both a teaching and a research component. Typically, the research component carries more weight for (research) universities than for universities of applied sciences (Fachhochschulen), but the exact ratio varies by Laender (e.g. Berlin applies a 50/50 ratio for universities and a 80/20 ratio for Fachhochschulen). The teaching component often consists of the number of students and graduations, whereas the research component is often distributed on the amount of external funding and the number of PhD graduations (Van Daalen et al, 2014 as quoted in Jonkers & Zacharewicz, 2015.).

During the past years, the funding of higher education has increasingly turned towards indicator-based funding. On top of this, Laender started to implement state-wide pacts and individual target-agreements as a complementary steering instrument. An important thing to note about these target-agreements is that they are not directly linked to financial rewards and/or penalties (Van Daalen, 2014 as quoted in Jonkers & Zacharewicz, 2015; see also De Boer et al (2015) for further description of the German situation)..

The Pact for Research and Innovation ('Pakt fuer Forschung und Innovation') has been a major driver for non-university institutional funding for public R&I in Germany in recent years. The initial agreement between the Federal Government and the Laender governments encompassed the years 2005 to 2010 and was extended in 2009 for the years 2011-2015 ('Pakt II'). The Pact for Research and Innovation increased the institutional funds annually by 5% for the German Research Foundation DFG and the main non-university research organisations Max Planck Society (MPG), Fraunhofer Society (FhG), Helmholtz Association (HGF), and Leibniz Association (WGL). Accordingly, institutional funding for these institutions (including funds for implementing the Initiative for Excellence through DFG) is 92% higher in 2015 compared with 2005 (GWK, 2015). R&I stakeholders in Germany, such as the Expert Commission on Research and Innovation (EFI) have welcomed the pact not just for the increase in funds but for secure planning coordinates which facilitate strategic decision making (EFI, 2014). The Federal Government and the Laender governments have agreed in December 2014 to extend the Pact for Research and Innovation until 2020 with annual budget increases of 3%⁴⁹. The Pact is being accompanied by mutually agreed research policy goals. In addition to early and systematic identification of cutting-edge research fields, promotion of junior scientists, improvement of the representation of women, inter-organisational networking and internationalisation, the main goals of the Pact include transfer of knowledge and technology and formation of sustainable partnerships with commercial partners.

⁴⁸ This section is based on Jonkers & Zacharewicz, 2015.

⁴⁹ <http://www.gwk-bonn.de/fileadmin/Papers/PFI-III-2016-2020.pdf> (8/2015)

Part of the pact agreement is the commitment of DFG and the main non-university research organisations to report annually to the Joint Science Conference ('Gemeinsame Wissenschaftskonferenz', GWK) of the Federal Government and the Laender governments. These reports culminate in a monitoring report which documents developments and practices (GWK, 2015). An initial stage in the allocation of institutional funding is the allocation across the main non-university research organisations which have distinct R&I profiles and organize the allocation of funds among their member institutes internally. Besides, DFG and the main non-university research organisations differ in the degree to which they are dependent on institutional funds, how they allocate resources between their institutes as well as how they adjust their research profiles (GWK, 2015):

- Max Planck Society (MPG)
MPG encompasses 83 institutes which conduct basic research in natural sciences, life sciences, social sciences, and the humanities. MPG had a total budget of €1.8b in 2014, 86% of which originate from institutional funds. MPG ties the review of existing departments or institutes to the retirement of their academic leadership. A process is initiated which can lead to changes in topics, extensions, closures or new foundations of departments or whole institutes. Between 2006 and 2014 10 MPG institutes experienced a change in research focus with new leadership, 5 institutes were newly founded and one institute was split up. MPG has a system of ex-ante, ex-post and extended evaluations through academic committees with strong international participation⁵⁰.
With regard to new research opportunities or requirements, the sections of MPG have perspective commissions which routinely evaluate medium and long-term opportunities. Besides, MPG has established a strategic innovation fund ('Strategischer Innovationsfond') to foster innovative topics and support excellent talents.
- Fraunhofer Society (FhG)
FhG consists of 67 institutes and research units which focus on the application of research and technology. FhG had a total budget of €2b in 2014, 31% of which originate from institutional funds. FhG distributes 60% of its institutional funds among its institutes based on an allocation rational which rewards in particular institutes with strong records for attracting competitive project funds ('Drittmittel') from the private sector. The rest is allocated through direct, internal competition based on evaluation processes. A central strategy fund exists for the support of new, strategic investments which are selected in a competitive process.
FhG identifies new research topics in multi-year cycles based on internal participation and technology foresight instruments. Anticipated demand by business and society are central drivers of portfolio development.
- Helmholtz Association (HGF)
HGF consists of 18 scientific-technical and biological-medical research centres which deal with long-term research questions. HGF had a total budget of €4b in 2014, 71% of which originate from institutional funds. HGF allocates institutional funds across programmes in six strategic research areas which span multiple research areas. The goal is to support interdisciplinary collaboration across research centres. The research programmes are evaluated by peer groups with the criteria of scientific quality and strategic relevance.
HGF evaluates its portfolio of research topics every five years. A competitive process exists for funding large, new strategic extension investments (>€15m) and temporary funding for supporting internal network and impulse activities.
- Leibniz Association (WGL)
WGL encompasses 89 research institutions focussing on societal, ecological and economic research questions. WGL had a total budget of €1.4b in 2014, 75% of

⁵⁰ <https://www.mpg.de/9704077/Evaluation2015.pdf> (1/2016)

which originate from institutional funds. Since 2011, each institute of WGL has a core budget ('Kernhaushalt') depending on their activity which increases annually according to the Pact for Research and Innovation. €30m are allocated annually in an internal competition and an additional €2m strategy fund exists through which the presidency of WGL can set strategic impulses across institutes. The identification of new topics is decentralized in WGL institutes which are supposed to form partnerships ('Forschungsverbuende') for working jointly on emerging scientific and societal research questions.

- German Research Foundation (DFG)
DFG had a total budget of €2.9b in 2014, 65 % of which originate from institutional funds. The rest stems from implementation of the Initiative for Excellence, programme allowance for indirect project costs and large research infrastructure. DFG evaluates its support instruments continuously with regard to changing demands from the community in different fields. In 2014 it enacted a review on structural effects and funding success across fields (see also section 3.4.3 of this report).
DFG supports the identification of new topics in a response-mode, i.e. it encourages self-directed research identification from applicants and creates research initiatives for particularly strategic topics or fields.

3.4.3 Project funding

Project funding for R&I in Germany (outside the portfolio of the German Research Foundation DFG) is organised in programmes and can be applied for by individuals, individual institutions or consortia of institutions ('Verbundprojekte'). The overriding goal is to fund projects which allow research to reach or sustain internationally competitive quality in a particular field (BMBF, 2014c). Indirect project funding exists (see also section 3.5 of this report) to support collaboration between public research institutes and the commercial sector, e.g. through the provision of research infrastructures, facilitation of networks, personnel exchange or other forms of collaboration. Apart from project research funding, contract research ('Auftragsforschung') exists in which ministries define research needs and appropriate the intellectual property of research outcomes (see also section 3.4.4 of this report on 'Ressortforschung') (BMBF, 2014c).

Universities in Germany received a total of €6.8b of competitive project grants in 2012 (DFG, 2015a). The largest share (roughly a third) originates from the German Research Foundation (DFG), followed by the Federal Government (25%), the private sector (20%) and the EU (10%). The biggest changes over time stem from an increasing importance of the Federal Government (2006: 19%) and EU sources (2006: 6%) and a reduction of importance of private sector funding (2005: 28%) (DFG, 2015a).

Among the largest recent initiative for public R&I is the Initiative for Excellence ('Exzellenzinitiative'). The original Initiative for Excellence was enacted in 2005 as a joint programme of the Federal Government (75% of funding) and the Laender governments (25% of funding). Total funding for this first round of the initiative was €1.9b (BMBF, 2014c). The Initiative for Excellence was renewed in 2009 until 2017 with a total budget of €2.7b. The Joint Science Conference (GWK) has commissioned an international expert commission with conducting the evaluation of the Initiative for Excellence.⁵¹ The commission reported final results in January 2016. The report concludes that the Initiative for Excellence had positive effects for R&I in many areas and recommends its extension with some adjustments (IEKE, 2016). . The Federal Government and the Laender governments have agreed in principle to extend the Initiative for Excellence beyond 2017.⁵²

⁵¹ <http://www.ieke.info/ieke> (10/2015)

⁵² <http://www.gwk-bonn.de/fileadmin/Papers/PFI-III-2016-2020.pdf> (8/2015)

The goal of the Initiative for Excellence is to support internationally excellent research at universities in Germany and make it visible. The initiative contains three programme lines and five years of funding (BMBF, 2009):

- Establishment of graduate schools for strengthening the training of junior researchers
45 graduate schools have been established since 2012 receiving 14.9% of initiative funds (DFG, 2015b)
- Excellence clusters for creating networks of excellent research
43 excellence clusters have been funded since 2012 receiving 56.6% of initiative funds (DFG, 2015b)
- Future concepts for particularly promising research projects
11 future concepts have been funded since 2012 receiving 28.5% of initiative funds (DFG, 2015b)

Funding criteria are exclusively scientific in nature, encompassing excellence in research and training of junior researchers, interdisciplinary research and the creation of international networks as well as collaborations across and beyond universities (BMBF, 2009). The application evaluation commissions consisted exclusively of scientists (14 for graduate schools and excellence clusters, 12 for future concepts). The scientific commissions had the majority of the votes in the final grant commission which also included representatives of the Federal Government and the Laender governments.⁵³

Another major competitive project funding initiative as part of the new High-Tech Strategy of the Federal Government is the Leading-Edge Cluster Competition ('Spitzencluster-Wettbewerb') of BMBF.⁵⁴ The programme targets regional initiatives connecting scientific research with the private sector. The last round of selection occurred in 2012 and the programme will conclude in 2017 (BMBF, 2014c). 15 clusters in total were eventually selected to receive funding of up to €40m over 5 years. Applicants could choose topics freely. Applications were evaluated by an independent commission. The programme was evaluated in 2015 (Rothgang et al., 2015). The evaluation process is described by the Expert Commission on Innovation (EFI) as a model for future policy evaluations in Germany (EFI, 2015). The evaluation of the Leading-Edge Cluster Competition is generally positive. EFI (2015) expresses doubts that the competition should be repeated, given that expected returns are about to decline. In addition to the Leading-Edge Cluster Competition a funding measure for the Internationalisation of Leading-Edge Clusters, Future Projects, and comparable networks ("Internationalisierung von Spitzenclustern, Zukunftsprojekten und vergleichbaren Netzwerken") was initiated by BMBF in 2015. In the first of three rounds eleven selected projects will receive up to four million euros over a period of up to five years on the German side starting in 2016.⁵⁵

The German Research Foundation DFG provides project funding of three major types (excluding the Initiative for Excellence which it implements jointly with German Science Council, 'Wissenschaftsrat', on behalf of the Federal Government and the Laender governments) (DFG, 2015a):

- Individual grant programmes (€2.6b granted between 2011 and 2013):
These can be applied for by researchers (typically holding a PhD and working for universities or research institutes in Germany) for financing individual research projects, scientific networks or positions. Examples include Clinical Trials, Emmy Noether Programme or Reinhart Koselleck Projects (see also Annex 2 of this report for a list).⁵⁶

⁵³ https://www.bmbf.de/files/Auswahl_und_Begutachtungsverfahren_Exzellenzinitiative.pdf (10/2015)

⁵⁴ <https://www.bmbf.de/de/der-spitzencluster-wettbewerb-537.html> (10/2015)

⁵⁵ <https://www.bmbf.de/en/internationalisation-of-leading-edge-clusters-forward-looking-projects-and-comparable-1416.html> (4/2016)

⁵⁶ http://www.dfg.de/en/research_funding/programmes/individual/index.html (10/2015)

- Coordinated programmes (€3.4b granted between 2011 and 2013)
These programmes target universities and promote national and international collaboration. Grants can fund research groups or units (see also Annex 2 of this report for a list).⁵⁷
- Funding of research infrastructure (€459m granted between 2011 and 2013)
These grants can fund large research equipment, scientific literature- or information systems (see also Annex 2 of this report for a list).

Apart from these project funding lines, DFG also funds a number of prizes which together with grants for other recipient groups accounted for €155m between 2011 and 2013. Individual grant programmes account for roughly three quarters of the budgets for coordinated programmes. While there is no optimal ratio between the two funding components, there is no obvious indication that this ratio may create disadvantages for public R&I in Germany.

Funding is typically the result of a bottom-up process of peer review. The review process is sophisticated and multi-layered:⁵⁸ The DFG head office appoints peer reviewers with relevant expertise (roughly 15,000 annually) while avoiding conflicts of interest. The reviewers evaluate academic excellence, relevance and originality of the proposals. The so-called review board, the members of which are selected from the scientific community, evaluates and compares the reviews for selection of the most promising proposals (DFG, 2015a). The review process is international. Almost a third of all reviewers work outside Germany with the largest group working in the US (8.8%) (DFG, 2012). In 2014 34% of all new individual grant applications were successful; for coordinated programmes no overall comparable number exists, for graduate colleges the success rate was 30% (DFG, 2015b).

DFG has high, international standards of programme evaluations, encompassing all programmes, independent evaluators, quantitative assessments and considerations of both effectiveness and efficiency of resources.⁵⁹ Evaluations within the last three years included:

- Evaluation of International Research Training Groups 2015⁶⁰
- Statistical Information on the Development of the Heisenberg Programme (2015)⁶¹
- Interdisciplinary: Reviewing Across Discipline Boundaries (2013)⁶²
- Evaluation in Research and Research Funding Organisations: European Practices (2012)⁶³
- Evaluation of Transfer Projects in Collaborative Research Centres (2012)⁶⁴
- Gender Effects in Research Funding (2012)⁶⁵

⁵⁷ http://www.dfg.de/en/research_funding/programmes/coordinated_programmes/index.html (10/2015)

⁵⁸ http://www.dfg.de/foerderung/antragstellung_begutachtung_entscheidung_gutachtende/index.html (12/2014)

⁵⁹ http://www.dfg.de/en/dfg_profile/facts_figures/evaluation_studies_monitoring/evaluation_standards/index.html (10/2015)

⁶⁰ http://www.dfg.de/en/dfg_profile/facts_figures/evaluation_studies_monitoring/studies/study_international_rtg/index.html (10/2015)

⁶¹ http://www.dfg.de/en/dfg_profile/facts_figures/evaluation_studies_monitoring/studies/report_heisenberg/index.html (10/2015)

⁶² http://www.dfg.de/en/dfg_profile/facts_figures/evaluation_studies_monitoring/studies/report_interdisciplinarity/index.html (10/2015)

⁶³ http://www.dfg.de/en/dfg_profile/facts_figures/evaluation_studies_monitoring/studies/report_interdisciplinarity/index.html (10/2015)

⁶⁴ http://www.dfg.de/en/dfg_profile/facts_figures/evaluation_studies_monitoring/studies/study_tfp_crc/index.html (10/2015)

⁶⁵ http://www.dfg.de/en/dfg_profile/facts_figures/evaluation_studies_monitoring/studies/study_gender_effects/index.html (10/2015)

Evaluations have been generally used for documenting the progress or success of programmes or across programmes. Accordingly, evaluations have provided inputs for decisions of steering or review commissions by highlighting potentials for improvements or extensions.

Other initiatives have been put in place at the Laender level. The state of Baden-Wuerttemberg emphasizes for example research at technology colleges which have a high potential to create fruitful knowledge flows between science and business (NRP, 2014). Another example is Hesse which structures interactions between science, business and politics through a "House of" strategy for central state themes: finance, IT as well as logistics and mobility (NRP, 2014).

3.4.4 Other allocation mechanisms

A relatively new instrument of R&I funding in Germany is the programme allowance for indirect project costs ('DFG Programmpauschale') of grants from the German Research Foundation (DFG) and most project funded directly through BMBF, which accounted for 20% of grants. As part of the Higher Education Pact 2020 it will increase to 22% of project grants starting in 2016.⁶⁶ The Laender will cover 2% while the Federal Government will fund 20%. The Expert Commission for Innovation (EFI) had stressed the necessity and benefits of an increase in such budgets for covering project-related costs at universities in the past (EFI, 2014).

A particular feature of the German R&I system are service providers for project management ('Projekttraeger'). These project management agencies are typically part of larger research institutes and provide a variety of services related to the funding programmes of ministries of the Federal Government. Their services encompass activities such as communicating programme calls, informing and consulting potential applicants, preparation of decision making, dissemination of results, coordination of partners and activities as well as project controlling (BMBF, 2014c). Some ministries have developed selection criteria and procedures which allow the project management service providers ('Projekttraeger') not just to prepare grant decisions but to conduct them.

Besides, there exist Federal research institutes which provide ministries with specifically relevant scientific knowledge for political consulting, transfer to legislation and standardization and legal tasks like type approval, quality assessment or safety standards ('Ressortforschungseinrichtungen'). R&D budgets of these institutes reached €965m or 7.2% of R&D funding of the Federal Government (BMBF, 2014c). They are planned to reach €971m in 2014. Examples of these institutes include the National Metrology Institute of Germany ('Physikalisch-Technische Bundesanstalt', PTB) under the authority of BMWi, responsible for precise, reliable and internationally acknowledged measurements or the Robert Koch Institute (RKI) working in the field of biomedicine, e.g. for the identification and surveillance of diseases. All institutes of this category have been evaluated by the German Council of Science and Humanities ('Wissenschaftsrat') between 2004 and 2010 with the goal of securing and extending academic excellence (BMBF, 2014c). A new round of evaluations is ongoing.

Finally, BMWi provides support for the commercialisation of research results from science in Germany. Technology Alliance ('TechnologieAllianz')⁶⁷ provides an online platform for the commercialisation of knowledge from universities and research organisations (for more information see chapter 5.6).

⁶⁶ <https://www.bmbf.de/de/dfg-programmpauschale-513.html> (8/2015)

⁶⁷ <http://www.technologieallianz.de/angebote.php> (10/2015)

3.5 Public funding for private R&I

3.5.1 Direct funding for private R&I

Funding for private R&I in Germany occurs in multiple forms. The Federal Government has undertaken efforts to re-structure the funding system in particular for SMEs with the goal of increased transparency (Deutscher Bundestag, 2015a). The system is now built around four central pillars: entrepreneurship, competence creation, pre-competitive research and technology transfer as well as application of R&D for commercialisation.

The Federal Government provides a range of support initiatives to facilitate entrepreneurship from science by addressing various needs (see also section 5.2 of this report) (BMBF, 2014c):

- **EXIST – Existenzgründung aus der Wissenschaft⁶⁸:**
The programme of BMWi was initiated in 1998 and is co-financed by the European Social Fund (ESF). It provides a range of instruments to entrepreneurs from academia. As part of the broader programme, EXIST wants to foster an entrepreneurial culture in universities through the competition “EXIST-Gruendungskultur.” 120 universities have developed and submitted concepts, from which 22 universities with the most promising concepts have been chosen and receive support for the implementation of their concepts. “EXIST-Gruenderstipendium” provides yearlong scholarships for potential entrepreneurs from universities and research organisations. The scholarship is supposed to facilitate the pre-entrepreneurship stage in which potential founders develop business plans. Roughly 150 scholarships are granted annually. “EXIST-Forschungstransfer” provides bridge funding for the development of technologically advanced research projects into commercial applications. It has resulted in 90 new firms since 2007. EXIST has been reformed in December 2014 with increases in available funds⁶⁹. Scholarships (EXIST-Gruenderstipendium) increase by 25% and the included funds for investments can now reach €30,000 instead of €17,000. Within EXIST-Forschungstransfer available investments in high tech projects increase from €70,000 to €250,000.
- **High-tech Start-Up Fund (‘High-Tech Gründerfonds’, HTGF)⁷⁰:**
HTGF was initiated in 2005 in collaboration of BMWi, government controlled banking group KfW and industrial partners with an investment endowment of €272m. The purpose of HTGF is to address particular funding needs of new firms for which it can be extremely difficult to attract lender or private equity investors. HTGF provides equity financing of up to €500,000 for newly founded technology firms. HTGF provides also access to a network of certified coaches and venture capital investors for future investment rounds. HTGF has 330 investments in its portfolio (March 2014) and has provided support for investments of third parties of roughly €600m.
- **ERP-Startfonds⁷¹:**
ERP-Startfonds provides equity financing for small technology-intensive firms during the early stages of their development. Financing is supposed to enable these firms to invest into R&D as well as commercialisation. ERP-Startfonds has financed roughly 500 technology-intensive firms since its creation. The fund works on the principle of co-financing with a lead investor (e.g. venture capital fund). The fund matches the investment of the lead investor if the latter provides management support to the focal firm. The fund can invest up to €5m in a particular firm.

⁶⁸ <http://www.exist.de/DE/Home/inhalt.html> (10/2015)

⁶⁹ <http://www.bmw.de/DE/Presse/pressemitteilungen.did=674028.html> (10/2015)

⁷⁰ <http://high-tech-gruenderfonds.de/en/> (10/2015)

⁷¹ <https://www.kfw.de/inlandsfoerderung/Unternehmen/Gr%C3%BCnden-Erweitern/Finanzierungsangebote/ERP-Startfonds-%28136%29/> (10/2015)

- INVEST – Zuschuss Wagniskapital⁷²:
INVEST provides incentives to private investors such as Business Angels who can receive 20% of their investment (maximum €250,000) into a young, innovative firm back from the Federal Government if they hold their initial equity investment (minimum €10,000) for three years. INVEST started in 2013 and has received 1,000 investor applications between May 2013 and December 2014 (EFI, 2015). Grants for a total of €11.7m were approved during this period corresponding to a total investment sum of €58.6m.
- IKT Innovativ⁷³:
IKT Innovativ is an entrepreneurship competition for newly founded firms with IT products or services at their core. Potential entrepreneurs compete with start-up plans which are evaluated by experts. The potential founders also receive coaching, feedback and access to professional networks. The winners receive start up grants of up to €30,000.

Research organisations also provide initiatives for science-based entrepreneurship which are typically financed by BMBF. Examples include the Life Science Incubator of the cancer research centre in Bonn or Helmholtz Enterprise. The latter can for example provide funding for up to three years for researchers from the Helmholtz society for developing business plans and commercialisation strategies⁷⁴.

With regard to competence creation and technology transfer, many policy instruments aim at creating interaction, knowledge spillovers and technology transfer between scientific research and firm R&D. Some programmes emphasize geographical proximity which can foster the efficiency of knowledge flows between science and industry because of direct interaction between scientists and the establishment of channels based on social networks. Among those are the Leading-Edge Cluster Competition ('Spitzencluster-Wettbewerb') (see also section 3.4.3 of this report) from BMBF in which the Federal Government has invested €360m since 2008 up to the end of 2014⁷⁵ and the initiative 'Unternehmen Region' of BMBF⁷⁶. The initiative 'Zwanzig20 –Partnerschaft für Innovation' of BMBF follows a similar approach. It creates a competition between interdisciplinary consortia including firms to develop joint innovation strategies. The initiative provides €500m until 2019 for developing joint innovation strategies based on a competitive assessment⁷⁷.

Apart from these cluster initiatives, the German Federation of Industrial Research Associations (AiF) „Otto von Guericke“ plays a crucial role in connecting research and innovation. Its primary purpose is to bridge basic research and industrial application of innovation. It manages a network of 100 research associations for applied research across business sectors and including research organisations and universities. It has roughly 50,000 members from business and has provided public funding of €490m in 2013 mostly on behalf of BMWi as part of IGF and ZIM.⁷⁸ AiF is also representing the interests of the industrial research associations vis a vis policymakers. This decentralized structure allows AiF to react flexibly to changing research demands and opportunities, e.g. from Industry 4.0.⁷⁹

Given the importance of SMEs for the German economy, virtually every major R&I policy initiative involving business refers to the challenges and opportunities of SMEs. This includes the High-Tech Strategy as well as the Digital Agenda 2014-2017 (see section

⁷² <http://www.bmwi.de/DE/Themen/Mittelstand/Mittelstandsfinanzierung/invest.html> (10/2015)

⁷³ <http://www.gruenderwettbewerb.de/> (10/2015)

⁷⁴ http://www.helmholtz.de/en/research/technologietransfer/foerderinstrumente/helmholtz_enterprise/ (10/2015)

⁷⁵ http://www.bmbf.de/pub/WEDO_SCW_Broschuere_2014_barrierefrei_NEU.PDF (10/2015)

⁷⁶ <http://www.unternehmen-region.de/> (10/2015)

⁷⁷ <https://www.bmbf.de/presse/foerderprogramm-zwanzig20-partnerschaft-fuer-innovation-startet-639.html> (10/2015)

⁷⁸ <http://www.aif.de/en/about-aif.html> (10/2015)

⁷⁹ <http://www.aif.de/home/detailansicht/news/fir-gewinnt-als-teil-des-nrw-konsortiums-im-wettbewerb-des-bundeswirtschaftsministeriums.html> (10/2015)

2.1 of this report). Several innovation policy instruments are particularly directed at SMEs. Among the most important ones are (BMBF, 2014c):

- Central Innovation Programme for SMEs ('Zentrales Innovationsprogramm Mittelstand' ZIM)⁸⁰:
ZIM is an initiative of BMWi to strengthen innovativeness and competitiveness of SMEs in Germany. ZIM is not limited to a particular industry or technology field. Criteria for financial support through ZIM are the innovation content and commercialisation potential of a project. Otherwise, SMEs have a high degree of flexibility within ZIM. They can choose topics, conduct project R&I in-house or collaborate with a university or research institute. ZIM also supports the creation of innovation networks across firm boundaries. ZIM has approved 29,000 projects since its start in 2008.⁸¹ The Federal Government budgets €513m for ZIM in 2014 which has provided a total of €3,9b in grants since 2008. A recent ZIM monitoring report from September 2014 highlights the flexibility of ZIM grant applications as a major advantage from the perspective of firms as well as its positive effects on private R&D investment and employment⁸²:
- ERP-Innovation Programme ('ERP-Innovationsprogramm')⁸³:
The programme targets the needs of SMEs to finance innovation activities which do typically not provide significant collateral for bank lending or only at high interest rates. Two combinable financing options are available: a regular loan with usually below-market interest rates and/or a subordinated credit tranche for which no collateral has to be provided. ERP-Innovation Programme is administered by government owned promotional bank KfW. The programme is designed to provide loans for applied R&D in SMEs. Repayment plans are designed to incorporate the time for commercialisation of the underlying innovation. Loans in the amount of €1.329m for 629 applications have been provided in 2014.
- KMU-innovativ⁸⁴:
KMU-innovativ is an initiative by BMBF targeting excellent research and innovation with high commercialisation potential of SMEs within nine technology fields: biotech, medical devices, ICT, nanotech (from 2016 extended to materials in general), production technology, technology for resource and energy efficiency, photonics, electronic systems and e-mobility as well as research for civil security. KMU-innovativ provides a special piloting service to potential applicants and a fast application process which is also attractive to small SMEs. The programme provided €100m in grants in 2012 to SMEs directly (60%) and their research partners.
- Innovation vouchers ('BMWi-Innovationsgutscheinen', go-Inno)⁸⁵:
Within this programme BMWi provides up to 50% of financing for professional consulting through accredited consulting firms for SMEs through a voucher system. Consulting can target product innovations ('go-innovativ') or process innovations ('go-effizient'). Voucher recipients report that 80% started an R&D-project or had substantial cost reductions (€200,000 annually) (BMBF, 2014c).
- Apart from these programmes there are also initiatives with a regional or topical focus such as for Innovation Competence in East Germany ('Innovationskompetenz INNO-KOM-Ost') or climate change ('Nationale Klimaschutzinitiative') (BMBF, 2014c).

⁸⁰ <http://www.zim-bmwi.de/> (10/2015)

⁸¹ <http://www.zim-bmwi.de/aktuelles/staatssekretaerin-gleicke-uebergibt-20.000-zim-zuwendungsbescheid> (10/2015)

⁸² <http://www.zim-bmwi.de/download/studien-berichte-expertisen/rkw-studie-09-2014> (10/2015)

⁸³ <https://www.kfw.de/inlandsfoerderung/Unternehmen/Innovation/Finanzierungsangebote/ERP-Innovationsprogramm-%28180-185-190-195%29/> (10/2015)

⁸⁴ <http://www.bmbf.de/de/20635.php> (10/2015)

⁸⁵ <http://www.innovation-beratung-foerderung.de/INNO/Navigation/DE/go-Inno/go-inno.html?sessionid=41D0A72EF834602311550032AFBE2E0C> (10/2015)

Additionally, the Federal Government has enacted a new law for the reduction of bureaucratic burden particularly for SMEs ('Bürokratieentlastungsgesetz') based on lower requirements for reporting and tax accounting.⁸⁶ Parliament has approved the law in July 2015 (Deutscher Bundesrat, 2015) and the Federal Government has accompanied it with a commitment to offset new bureaucratic burdens on firms with the reduction of existing ones ('Bürokratiebremse').⁸⁷ However, the impact assessment which accompanies the new law could not identify an expected effect on firm innovation (Kienbaum, 2015).

Focusing on support for commercialisation, the programme "Protection of Ideas for Commercial Use" ('Schutz von Ideen für die Gewerbliche Nutzung', SIGNO)⁸⁸ of BMWi has been targeting universities, companies and inventors since 2008. The goals of the program are to provide information and promote strategic thinking about commercial use of inventions. The monitoring report of SIGNO from June 2014 shows that SIGNO has led to 542 patent applications, 530 patent sales and 375 licensing agreements among other outcomes since 2008⁸⁹. The report concludes that the programme has performed well in creating awareness and momentum for commercialisation strategies but requires adaptations to the needs of various stakeholder groups (Kulicke, 2014).

Funding instruments undergo regular evaluations following international standards. Examples include the evaluation of the Central Innovation Programme for SMEs (ZIM) (Kulicke, 2014), the evaluation of EXIST⁹⁰ or KMU-innovativ.⁹¹ The Expert Commission for Innovation (EFI) emphasizes the need for more systematic and professionalized evaluations in general (EFI, 2014) and recommends the evaluation of the Leading-Edge Cluster Competition ('Spitzencluster-Wettbewerb') as a template (EFI, 2015).

The Federal Government promotes active participation in Horizon 2020 through a dedicated website and a national contact point⁹². Further, it provides support for the internationalisation of Leading-Edge Clusters, Future Projects, and comparable networks ('Internationalisierung von Spitzenclustern, Zukunftsprojekten und vergleichbaren Netzwerken') which is now a BMBF programme with three yearly funding rounds between 2015 and 2017 (see 3.4.3). In each round cluster or network managements can apply for funding for the development of internationalisation concepts (up to two years) and implementation (up to three years)⁹³.

In sum, the government funding for private R&I covers the stages from research to commercialisation comprehensively. They include both accesses to financing as well as knowledge. Particular attention is paid to the needs and opportunities of SMEs ('Mittelstand') and many programmes aim at leveraging interaction between scientific research and firm R&D. In particular the German Federation of Industrial Research Associations (AiF) „Otto von Guericke“ can react flexibly to changing demands and opportunities because of its decentralized structure and integration with firms. Central Innovation Programme for SMEs (ZIM) is the dedicated policy instrument targeting SMEs. Innovative approaches include vouchers for professional consulting of SMEs without dedicated innovation management or controlling functions.

In terms of lead market initiatives, the new high-tech strategy (BMBF, 2014d) of the Federal Government identifies six future challenges with major opportunities for economic growth and prosperity: Digital economy and society, sustainable economy and energy, innovative employment, healthy living, intelligent mobility as well as civil

⁸⁶ <http://www.bmwi.de/DE/Themen/Mittelstand/buerokratieabbau.did=508704.html> (10/2015)

⁸⁷ <http://www.bmwi.de/DE/Presse/pressemitteilungen.did=719462.html> (10/2015)

⁸⁸ <http://www.signo-deutschland.de/> (10/2015)

⁸⁹ http://www.signo-deutschland.de/e5072/e13035/SIGNO_Erfolgskontrolle_Endbericht_FraunhoferISI.pdf (12/2014)

⁹⁰ <http://www.bmwi.de/BMWi/Redaktion/PDF/Publikationen/EXIST/exist-0311.property=pdf.bereich=bmwi.sprache=de.rwb=true.pdf> (10/2015)

⁹¹ <http://ftp.zew.de/pub/zew-docs/gutachten/KMU-innovativ2012.pdf> (10/2015)

⁹² <http://www.horizont2020.de/beratung-nks.htm> (10/2015)

⁹³ <http://www.bmbf.de/de/25370.php> (10/2015)

security. These can be consistently be seen reflected in other policy initiatives such as the Leading-Edge Cluster Competition or the Digital Agenda 2014-2017 (BMW, 2014a).

3.5.2 Public Procurement of Innovative solutions

Due to the lack of standardised statistics, estimates for the total value of public procurement in Germany vary between €200b and €496b per year which corresponds to 12%-13% of GDP (Kienbaum, 2014). Municipalities account for the lion's share of public procurement and federal and state governments for the remainder. A study carried out in 2009 showed that innovation-relevant procurement made up about 10% of total procurement and that IT, telecommunications, energy, the environment, R&D, facility management and construction services are the sectors of German economy with most potential for public procurement of innovative products and services (OECD, 2011).

Legal Public Procurement framework

Germany transposed the two 2004 Directives on public procurement (2004/17/CE and 2004/18/CE) into national law in 2006. The changes adopted in the EU Directives have been incorporated into several different already existing German legal acts. The above guidelines have been codified by law in the Act against Restraints of Competition ('Gesetz gegen Wettbewerbsbeschränkungen', GWB), the Regulation on the Award of Public Contracts ('Vergabeverordnung', VgV), the Sector Regulation ('Sektorenverordnung', SektVO), the German Construction Contract Procedures ('Vergabe- und Vertragsordnung für Bauleistungen', VOB (public works)), the Procurement and Contract Procedures for Supplies and Services ('Vergabe- und Vertragsordnung für Leistungen', VOL) and the Procurement and Contract Procedures for Freelance Services ('Vergabeordnung für freiberufliche Dienstleistungen', VOF).

Article 16 of Directive 2004/18/CE and Article 24 of Directive 2004/17/CE including exemptions for R&D services were also transposed into national law and the corresponding provisions can be found in Article 100, paragraph 2, letter n of the Act against Restraints on Competition (GWB)⁹⁴.

Recent public procurement Directives 2014/24/EU (replacing Directive 2004/18/EC), 2014/25/EU (replacing 2004/17/EC) and 2014/23/EU have to be transposed into German law until April 2016. Responsible authority for the implementation is the Federal Ministry for Economic Affairs and Energy (BMW). According to the Federal Government, the implementation of the new EU public procurement directives should make procurement procedures in Germany more flexible and user-friendly while increasing legal certainty for companies and public procurers.

The PCP/PPI landscape in Germany

The concept of innovation-oriented public procurement has been included as a goal in several of the most important strategic documents of innovation policy at federal level, such as the Digital Agenda 2014 - 2017.

The Federal Government has made further steps towards innovative public procurement in 2015. It has proposed a reform of procurement law ('Vergaberechtsmodernisierungsgesetz - VergRModG') as part of a bureaucracy reduction initiative. The law would establish innovation as part of procurement decision making. The law is currently being debated in parliament. Furthermore, the Act against Restraints on Competition (GWB) was modified in 2009 in such a way that public procurers can also require innovative aspects in addition to social and environmental aspects in the service specifications⁹⁵.

⁹⁴ <http://www.bmwi.de/BMWi/Redaktion/PDF/Gesetz/achte-novelle-gwb.property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf>

⁹⁵ http://www.gesetze-im-internet.de/gwb/_97.html

In 2010 (updated in 2014), the German Ministry for Economic Affairs and Energy (BMWi) published a first version of practical guide on PPI with recommendations and best practice cases to help public sector organisations incorporate innovation procurement into their purchasing practices⁹⁶.

Particular emphasis has been put on resource efficient and sustainable procurement. In 2008, the Federal Cabinet adopted "General administrative provisions for procurement of energy efficient products and services" and corresponding guidelines which are binding for all departments at federal level⁹⁷. In 2010, the Alliance for Sustainable Procurement ('Allianz für nachhaltige Beschaffung') was formed under the chairmanship of Federal Government which has become the central portal for public sustainable procurement on all levels of public administration (Federal Government, Laender and municipalities). The Alliance for Sustainable Procurement issued guidelines for public actors on "resource efficient procurement" in 2014 and "procurement of electro and hybrid vehicles" in 2013 which were updated in February 2015⁹⁸. However, the Alliance prioritises environmental and social criteria rather than innovative aspects of procurement.

PCP/PPI initiatives

In 2012, the BMWi set aside a budget of €2.8m to start providing financial incentives to German public procurers to pilot PCP in Germany⁹⁹. The dedicated budget for 2013 added up to €3.8m with most of it earmarked for the creation of the KOINNO Competence Centre for Innovative Public Procurement, which was set up in 2013 under the auspices of BMWi¹⁰⁰. The Centre is managed by German Association Materials Management, Purchasing and Logistics (BME). It is advising procurers at federal, state and municipal level and aims to raise awareness about innovation-relevant public procurement at all levels of public administration. In addition, KOINNO is planning the launch of three pilot projects for PCP and runs a database with best practice examples for innovative public procurement.

Funding for pre-commercial procurement has also been integrated in some of the already existing federal grant schemes for innovation, such as "KMU innovativ" and the Central Innovation Programme SME¹⁰¹.

Moreover, the BMWi has been awarding a prize for best practice in public procurement of innovations "Innovation creates a lead" (Innovation schafft Vorsprung) since 2006.¹⁰²

Among the best documented pilot schemes for increasing demand for innovative products through public procurement is the support for electric mobility in city and traffic planning ('Elektromobilität in der Stadt- und Verkehrsplanung'). The Federal Ministry for traffic and digital infrastructure ('Bundesministeriums für Verkehr und digitale Infrastruktur', BMVI) has provided financial support of €850m between 2006 and 2015 for the scheme although detailed budget for procurement are not available. Since 2009 fleets and charging infrastructure have been put in place in several model regions. Examples are the "LivingLab BWe mobil" in Baden-Württemberg, the "Internationales Schaufenster Elektromobilität" in Berlin-Brandenburg, "Unsere Pferdestärken werden elektrisch" in Lower Saxony and the project "Elektromobilität verbindet" in Bavaria and Saxony. Altogether, 90 common projects are being realised in these four model regions between 2012 and 2016. One concrete example for such a project is an EU-wide

⁹⁶ http://de.koinno-bmw.de/system/publications/files/000/000/201/original/BMWi_Leitfaden_KOINNO_web.pdf?1400241968

⁹⁷ <http://www.bmw.de/BMWi/Redaktion/PDF/A/aa-v-zur-beschaffung-energieeffizienter-produkte.property=pdf.bereich=bmw2012.sprache=de.rwb=true.pdf>

⁹⁸ http://www.nachhaltige-beschaffung.info/SharedDocs/Kurzmeldungen/DE/2014/140213_AnB_2014.html

⁹⁹ <http://cordis.europa.eu/fp7/ict/pcp/docs/pcp-germany-v1.pdf>

¹⁰¹ <http://www.koinno-bmw.de/information/forderprogramme>

¹⁰² <http://www.koinno-bmw.de/innovation/innovationspreis>

tendering process initiated by the state of Berlin for the expansion of its e-car charging facilities from about 220 to 1600 charging points¹⁰³.

On European level, Germany is participating in several EU funded projects that include pre-commercial procurement such as THALEA, IMAILE and HBP. In the framework of THALEA¹⁰⁴, a group of procurers (learning institutions such as schools and universities) from several EU countries are preparing a joint PCP under German law in the field of telemedicine for Intensive Care Unit patients at increased risk. IMAILE¹⁰⁵ is the first project on a European level which addresses the area of ICT in the field of Education and e-learning from both the demand and the supply side. The HBP (Human Brain Project)¹⁰⁶, focusing on simulation of the human brain using supercomputers, is conducting pre-commercial procurement under German law of interactive super computers that will be used to replicate and study the human brain. The procurement is now in its final phase.

However, binding strategies or concrete national targets across all public bodies for PCP or PPI do not exist. The EFI Expert Commission which is advising the Federal Government on research and innovation matters concluded in its 2013 report that Germany is not sufficiently exploiting the potential of innovation-oriented procurement yet. An important step in this process is overcoming the fragmentation of public procurement in Germany. An estimated 30,000 different government procurement offices at federal, Laender and municipality levels exist (EFI, 2013). Current policies focus on dealing with fragmentation before setting input or output goals.

Much potential also still seems to exist at the level of municipalities in Germany. A study carried out by KPMG in 2013 covering 56 German municipalities revealed that still only a minority of municipalities considers procurement as a driver for innovation that could help achieve strategic objectives of the municipality¹⁰⁷.

On the other hand, recent analyses for Germany show that public procurement is as important for firm innovation performance as industry-science linkages (Aschhoff and Sofka, 2009). What is more, the effect is particularly strong for firms in Germany which may otherwise not participate in government R&I policies, i.e. small firms, firms in service sectors and firms in economically less developed East Germany.

3.5.3 Indirect financial support for private R&I

R&I funding in Germany does not include R&D tax credits. The introduction of R&D tax credits has been on the political agenda for some time. However, the current government seems less inclined to introduce them compared with the previous one (EFI, 2014). While there is no explicit R&D tax credit, expenditures for R&D reduce a firm's taxable income if they constitute costs. According to German income tax law, all current R&D expenditures are fully deductible from taxable income. Capital assets of a company and acquired know-how can be subject to depreciation or a reduction in value.

3.6 Business R&D

3.6.1 The development in business R&D intensity

As one can see from Figure 7, the German BERD has been following a growing trend since 2005 and in the years 2010-2012 it is close to an intensity of 2%. The service and manufacture sectors amount together to more than 95% of the German BERD. In particular, manufacturing is extremely important and strongly correlated to the total BERD. The business sector (Figure 8) is by far the main funder of the German BERD. The contributions from abroad and from the government are of a comparable intensity, in both cases much lower than those of the business sector and only play a minor role.

¹⁰³ http://schaufenster-elektromobilitaet.org/de/content/ueber_das_programm/programmuebersicht.html

¹⁰⁴ <http://www.thalea-pcp.eu/>

¹⁰⁵ <http://www.imaile.eu/>

¹⁰⁶ <https://www.humanbrainproject.eu/>

¹⁰⁷ http://www.publicgovernance.de/docs/Studie_Kommunale_Beschaffung_im_Umbruch.pdf, p.16

As for the impact on the economic crisis on business R&D spending, business R&D expenditures contracted in 2009 (-1.7%), but much less so than nominal GDP which left business R&D intensity unscathed.

During the years following the crisis positive trends in BERD growth could be observed. This dynamic was broken in 2013 when BERD slightly contracted, However, in 2014 BERD grew again moderately. Under this relatively calm surface, some further changes are observable. Recent data by Germany's Stifterverband show that expenditures by German businesses for extramural performed R&D have strongly been increasing in 2013, in particular in chemical and pharmaceutical industries (+17% and +19% respectively) while intramural expenditures have been slightly declining. A major part of the additional extramural expenditure is spent in small specialised service oriented SMEs. Consequently, intermural R&D expenditures of independent scientific and technological service providers have increased by 13.3% between 2012 and 2013 (Nace-Code "M"). This is an indication for more open corporate innovation strategies characterised by increased usage of external knowledge and competence. The coming years will have to show whether this trend is solidifying. Generally, it can be noted that over the past 20 years intramural business R&D expenditures doubled while extramural expenditures quadrupled (Stifterverband, 2015d).

Figure 7: BERD intensity broken down by most important macro sectors
(C= manufacture, G_N=services)

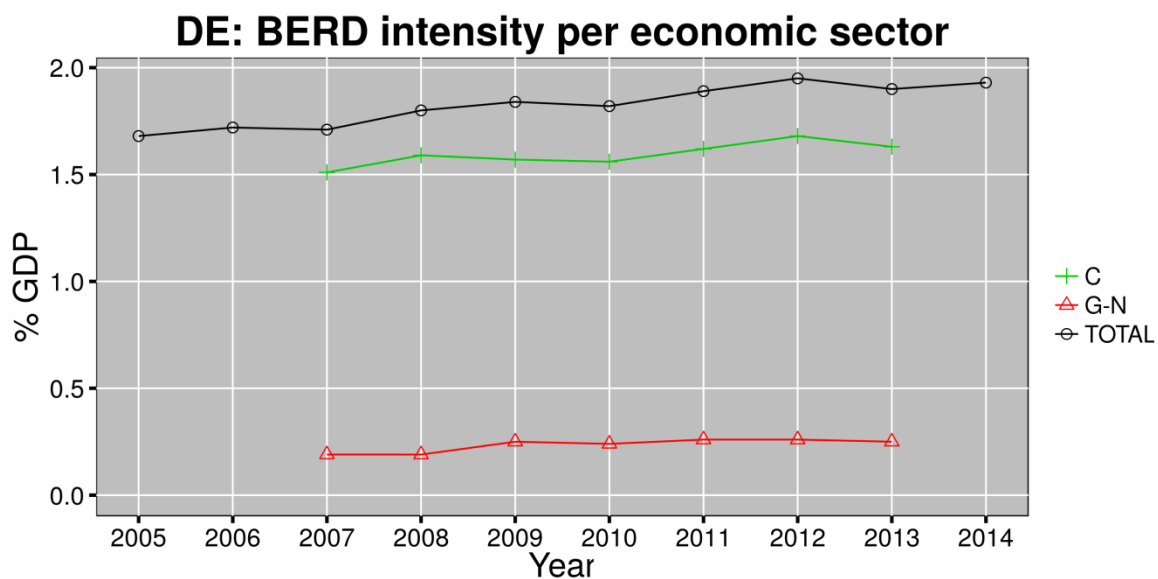
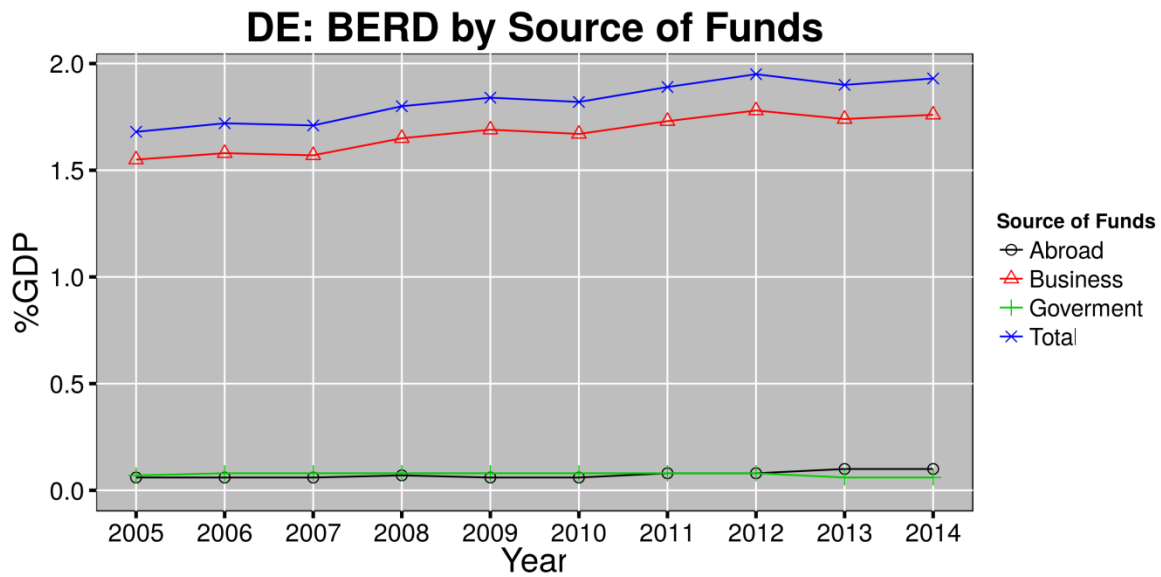


Figure 8: BERD by source of funds



3.6.2 The development in business R&D intensity by sector

Manufacturing increased its R&D intensity by 7.9% between 2007 and 2013, from an already high level of 1.51% to 1.63%. Over the same period R&D intensity in services increased by 31.6%, from 0.19% to 0.25%.

The automotive sector is the leading sector of the German manufacture (see Figure 9), followed at distance by the manufacture of computer, electronic and optical products and by the manufacture of other machinery and equipment. For the three sectors mentioned above, and in particular for the automotive sector, one can observe a growing trend after the dip in 2009. Other important sectors include pharmaceutical and chemical industries. The automotive sector in Germany is a particularly important contributor to R&D. It accounts for three quarters of all R&D investment in this sector in Europe and has increased R&D investments by 9.7% in 2013. In more general terms, firms on the R&D investment scoreboard headquartered in Germany have increased their R&D spending by 5.8% in 2013, compared with a worldwide increase of 4.9% and 2.5% of all EU headquartered firms. Volkswagen is the worldwide number one of all firms with R&D investments reaching €13.1b or 6% of sales in 2014.

As for the impact on the economic crisis on business R&D spending, it was observed that business R&D expenditures contracted in 2009 (-1.7%), but much less so than nominal GDP. On closer examination, it becomes obvious that manufacturing was hit the strongest with R&D expenditures dropping by 5% in 2009. In the automotive industry, R&D expenditures plummeted by about 10% and in electronic engineering by more than 10%. It is due to very positive developments in ICT services and professional, scientific and technical service activities (Figure 10) that business R&D contracted only very moderately during the crisis. This positive trend in services had started already a little earlier but continued unabatedly over 2009 and 2010. In important sectors like automotive and electronics, it took until 2011 for R&D expenditures to reach pre crisis levels (Stifterverband, 2012) (see also Figure 9).

Figure 9: top sectors in manufacturing

(C26=manufacture of computer, electronic and optical products; C28=manufacture of machinery and equipment n.e.c.; C29=manufacture of motor vehicles, trailers and semi-trailers).

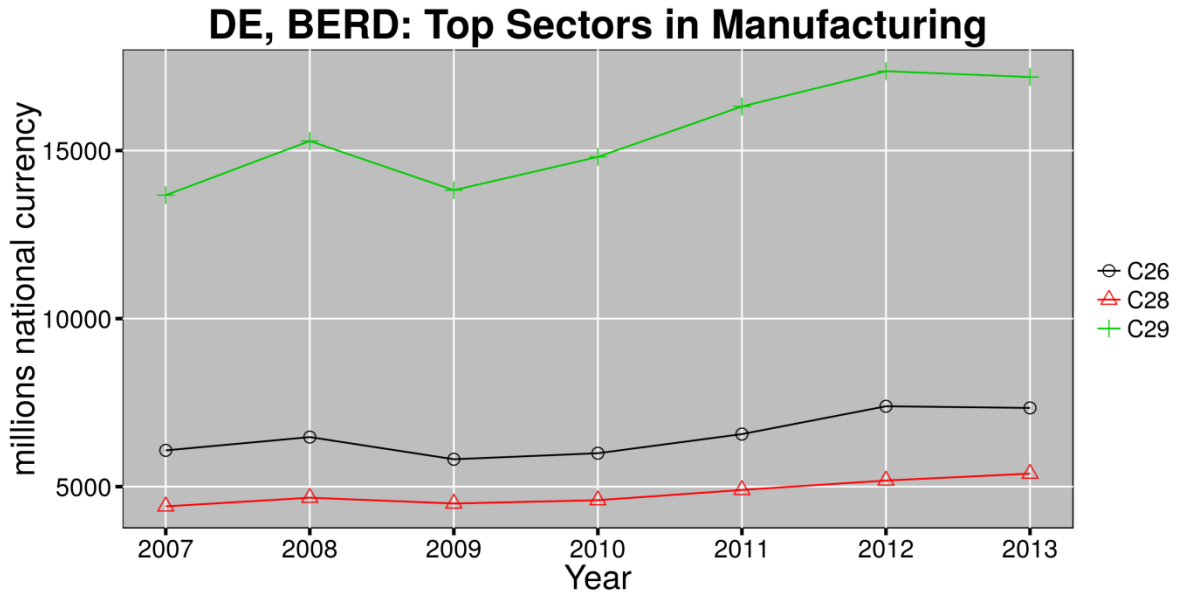
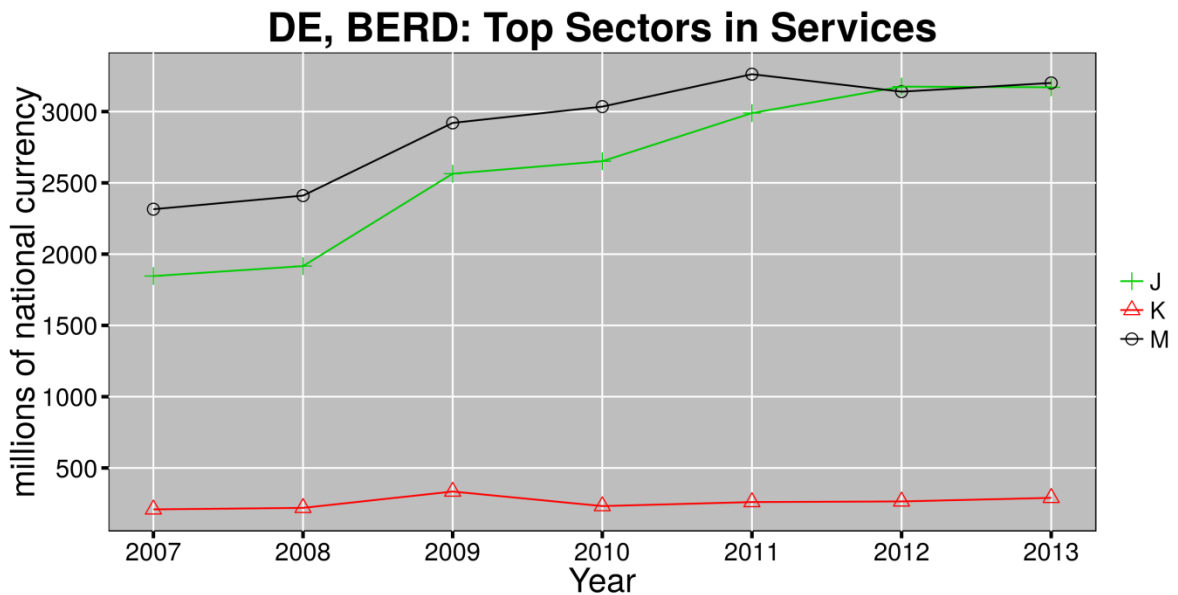


Figure 10: top service sectors

(J=information and communication, K=financial and insurance activities, M=professional, scientific and technical activities).



As mentioned above, the importance of the ICT and scientific/technical services which have been on the rise since 2008 stands out. In 2012, they are practically at the same nominal levels slightly above €3,000m. Enterprises in the ICT service sector are mostly smaller but they carry out above average amounts of R&D and they have come to dominate the ICT sector, in terms of turnover and value added as well as in terms of numbers of enterprises and employees.

3.6.3 The development in business R&D intensity and value added

Unsurprisingly, due to its importance in the German BERD, manufacturing is the biggest contributor to Gross Value Added (GVA) in Germany in 2012 (Figure 11). A top service sector in terms of BERD, namely the professional, scientific and technical activities also

appears as one of the most importance sectors in terms of GVA, in particular when putting it into relation to GVA in manufacturing broken down by most important sub sectors (Figure13). Finally, some services (like the real estate activities and the activities related to human health) are important in terms of their GVA, whereas they play a more modest role in the BERD.

Figure 11: economic sectors as percentage of the total GVA.

Top 6 sectors in decreasing order: 1) manufacture, 2) real estate activities, 3) wholesale and retail trade (repair of vehicles and motorcycles), 4) human health and social work activities, 5) professional, scientific and technical activities, 6) administrative and support service activities.

DE: GVA by Economic Sector (2014)

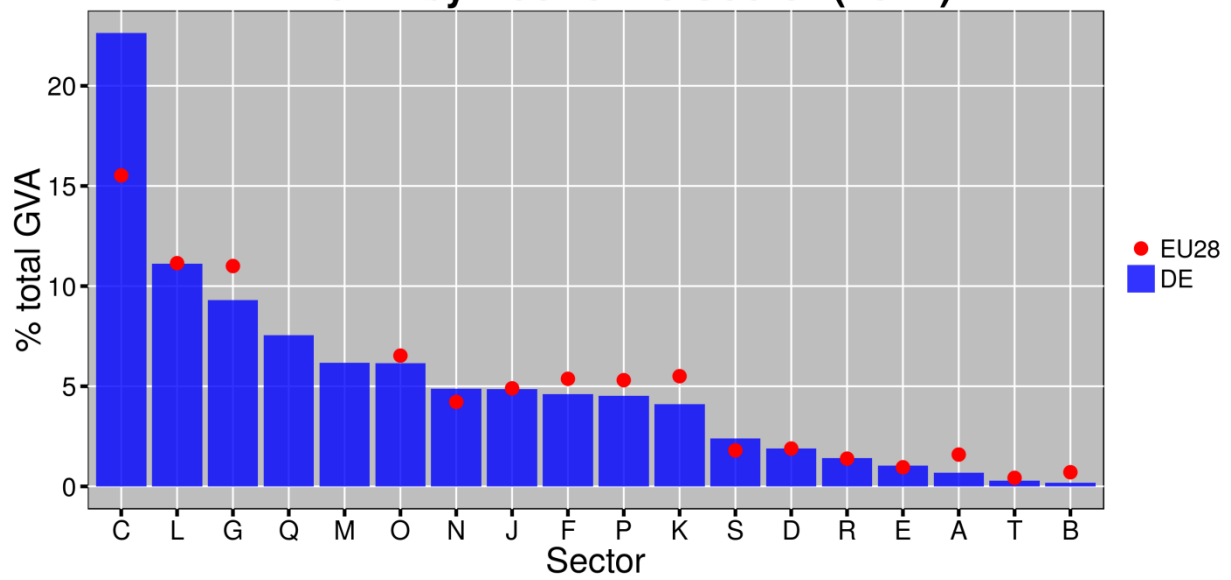
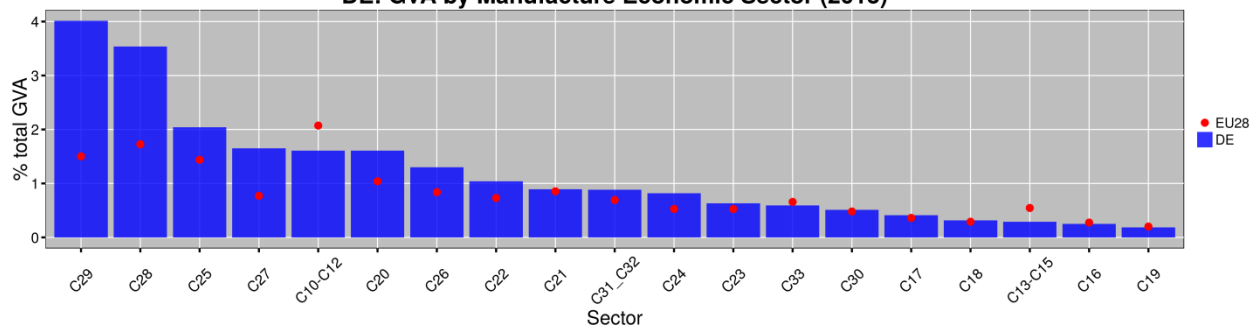


Figure 12: GVA in manufacturing.

Top 6 manufacturing sectors: 1) manufacture of machinery and equipment n.e.c., 2) manufacture of motor vehicles, trailers and semi-trailers, 3) manufacture of fabricated metal products except machinery and equipment, 4) manufacture of electrical equipment, 5) manufacture of food products, beverage and tobacco products, 6) manufacture of chemicals and chemical products.

DE: GVA by Manufacture Economic Sector (2013)

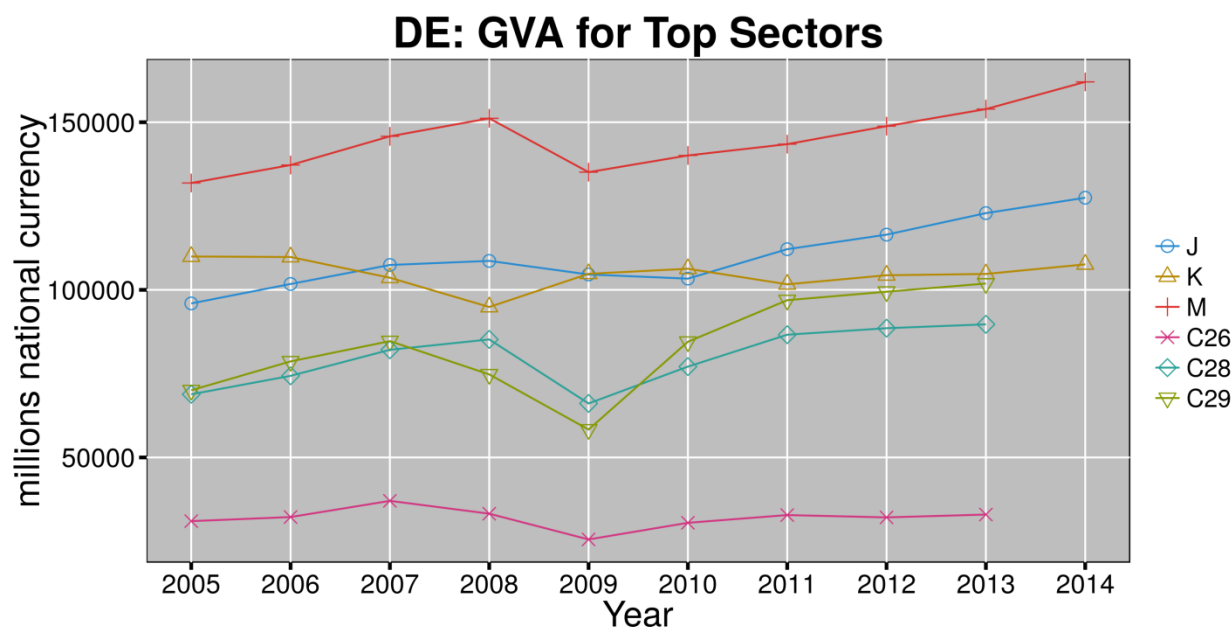


Consistently with the aforementioned importance of the automotive industry in the German economy, the manufacture of motor vehicles and machinery are the two leading sectors also in terms of GVA for the German manufacture. The food industry and the chemical industry also make important contributions to GVA (Figure 12).

One should also note the importance of SMEs for value added in Germany. The success of German SMEs throughout the crisis period of 2008-2014 is unique in the EU. The number of SMEs soared from 1.87 million in 2008 to almost 2.2 million in 2014. The number of people employed in German SMEs is estimated to have increased by some 2.8

million to a total of almost 16.85 million in 2014. The surge in total value added was estimated at 16 % across almost all sectors. This success story is set to continue at least for the near future. The number of SMEs is forecast to expand by 100 000 new firms in 2015 and 2016, creating an additional 820 000 jobs in the process. SMEs of all size classes are expected to create more jobs, most notably medium-sized ones with an expected increase of 3.1% a year¹⁰⁸.

Figure 13: Value added for the leading manufacture and service sectors in Figures 9 and 10.



3.7 Assessment

The system of R&I funding in Germany reflects the size and complexity of the economy as well as a federal tradition with important responsibilities of the Laender. Focussing on funding for public R&I in particular the Initiative for Excellence and the Pact for Research and Innovation have had positive effects. The former has been a major departure from the federal tradition of university funding in Germany. However, it has created positive dynamic of ambitious new research initiatives and doctoral training with scientific excellence in mind. The Pact for Research and Innovation has increased the planning horizon of the main research organisations and provided them with new funding. While their institutional funding is granted as a block, competitive mechanisms are in place within each organisation to allocate fund competitively among member institutes. Besides, the system of institutional funding for research organisations guarantees a general balance between basic and applied research. There are no indications that the German Research Foundation DFG is not functioning properly in organizing competitive allocations of funds for individual researchers as well as research units, institutes or universities.

¹⁰⁸ European Commission, DG GROW, Small Business Act (SBA) fact sheet Germany, http://ec.europa.eu/growth/smes/business-friendly-environment/performance-review/index_en.htm

Focusing on funding for private R&I, many efforts are undertaken to connect academic discovery in universities and research institutes with commercial application in firm R&D. The funding system is particularly geared towards the needs of SMEs. This is appropriate given the importance of this group of firms for the German economy and R&I system. Then again, current trends indicate that investment in innovation of German SMEs is slowing down (EFI, 2015) and their rate of success with innovative products has declined albeit from a high level (European Commission, 2015c). This trend requires further insights into cause and effect relationships.

4. Quality of science base and priorities of the European Research Area

4.1 Quality of the science base

The German science base performs generally above EU average (see table below). Scientists in Germany have produced more publications per capita (1.76) than the average of EU-28 (1.43) in 2013. The publications are more likely originating with international co-authors (47.5%, EU-28: 36.4%). It is also noteworthy that scientists in Germany produce publications of substantial quality as evidenced by citations to the original publications. More than 13% of publications from Germany reach the threshold of the top 10% in terms of citations between 2000-2013 compared with an EU-28 average of 11.3%. This strong positioning in terms of publication quality coincides with substantial investments of Federal and Laender governments to continuously provide additional resources to the German Research Foundation (DFG) and the main research organisations through the Pact for Research and Innovation (see section 3.4 of this report) as well as emphasizing high quality in research projects through the Initiative for Excellence (see section 3.4 of this report).

A recent survey of the business association Stifterverband among the leadership of universities in Germany finds that they assess the situation of their universities more positively (Stifterverband, 2015a). Moreover, university leadership reports improvements in the collaboration with politics.

German public scientists are substantially more likely to work with scientists from the business sector. Accordingly, 3% of all publications in Germany originate as public-private co-publication between 2011 and 2013, compared with only 1.8% of the average of EU-28. This reflects a broader trend in German R&I policy to interconnect public and private R&I. Initiatives in this direction emerge from the strengthening of regional clusters, e.g. through the Leading-Edge Cluster Competition or the German Federation of Industrial Research Associations "Otto von Guericke" (AiF).

Table 5: Indicators for quality of science base

Indicator	2013	EU average
Number of publications per thousand of population	1.76	1.43
Share of international co-publications	47.5%	36.4%
Number of international publications per thousand of population	0.83	0.52
Percentage of publications in the top 10% most cited publications	13.11 (2000-2013)	11.29 (2000-2013)
Share of public-private co-publications	3.0% (2011-2013)	1.8% (2011-2013)

Source: JRC IPTS RIO elaboration on Scopus data collected by Sciencematrix in a study for the European Commission DG RTD (Campbell, 2013). The share of public-private co-publications is derived from the Scival platform and is also based on Scopus data (September 2015). SciVal ® is a registered trademark of Elsevier Properties S.A., used under license. The data on public-private co-publications is not fully compatible with the data included in the IUS, due to differences in the methodology and the publication database adopted.

4.2 Optimal transnational co-operation and competition

4.2.1 Joint programming, research agendas and calls

Germany has participated in all initiatives towards increased R&I collaboration in Europe and internationally. The commitment towards further strengthening and developing ERA

is explicitly part of the coalition agreement of the Federal Government coalition in which it lays out its policy priorities until 2017. Accordingly, the Federal Government has formulated a strategy ('Strategie der Bundesregierung zum Europäischen Forschungsraum,' BMBF, 2014g) complemented by the BMBF's action plan for international collaboration ('Aktionsplan Internationale Kooperation,' BMBF, 2014a) in 2014.

The commitment of Germany to strengthening co-operation within ERA has steadily increased. BMBF's project funding for international projects with EU partners has reached €109m in 2013, an increase of 47% compared with 2009 (BMBF, 2014a). However, project funding for international projects with non-EU partners has almost doubled during the same time period (96%) and has reached €235m in 2013 (BMBF, 2014a). BMBF contributions for international research programmes and R&D infrastructures have reached €402m in 2013 (2009: €373m) (BMBF, 2014a). The Federal Government has set a goal for a 20% share of partners from abroad in BMBF funded projects in its internationalisation strategy (BMBF, 2008). This goal has already been reached (BMBF, 2014a).

The Federal Government formulates a vision for Germany's role within transnational co-operation and competition of ERA in its ERA strategy (BMBF, 2014g). This strategy envisions science in Germany as part of an intensified, visible European and international network but with the Member States as main actors for the further realization of ERA. The strategy encompasses the following instruments for co-operation:

- Strengthening the structural effects of Joint Programming Initiatives (JPIs) especially with a far reaching intent to incorporate European components in the planning of BMBF funding programmes reflecting the content of jointly agreed JPI research agendas.
- Continuation and increased use of other border-spanning initiatives and platforms of ERA such as European Innovation Partnerships (EIPs). The strategy document highlights the EUREKA and COST initiatives because of their bottom up approaches, flexibility and lean administration.
- Use and extension of public-public-partnerships (P2Ps) such as EUROSTARS for research funding of SMEs¹⁰⁹ and public-private-partnerships (PPPs) such as BBI the initiative for bio based industries¹¹⁰.
- Increase the visibility and documentation of the European and international networks of German science through new indicators. Additionally, BMBF has established an association for research marketing ('Aktionsbuendnis Forschungsmarketing') as a dialogue between science, business and politics which is supposed to analyse and design a framework for research marketing of Germany abroad (BMBF, 2014a).
- Continue, extend and support transnational co-operation through the research organisations such as DFG. Successful examples of mechanisms for transnational research support include the "Lead Agency" approach in Germany, Austria and Switzerland (D-A-CH) by which grant proposals can be submitted in one country and national research organisation coordinate among themselves.

The BMBF's action plan for international collaboration reflects this strategy (BMBF, 2014a). It emphasizes the joint programme planning based on JPI. Germany participates currently in 9 of the 10 JPIs¹¹¹. The action plan emphasizes topical choices for future programme planning which overlap with the key technological fields outlined in Germany's High Tech Strategy as well as the increasing importance of topics relevant to other countries, especially emerging economies. A notable initiative among the public

¹⁰⁹ <https://www.eurostars-eureka.eu/eurostars-expert-area> (12/2014)

¹¹⁰ <http://bbi-europe.eu/> (12/2014)

¹¹¹ <https://www.era-learn.eu/> (3/2016)

research organisations for increasing international co-operation is the opening of two newly founded Max-Planck institutes outside of Germany (BMBF, 2014a).

The action plan also demonstrates the awareness for monitoring. For this purpose BMBF will publish a biannual report on the internationalisation of the German research and science environment ('Bericht zur Internationalisierung in der deutschen Forschungs- und Wissenschaftslandschaft'). In terms of visibility of German science abroad, BMBF has established an association for research marketing ('Aktionsbündnis Forschungsmarketing') as a dialogue between science, business and politics which is supposed to analyse and design a framework for research marketing of Germany by 2015 (BMBF, 2014a).

In sum, R&I policy in Germany embraces transnational co-operation and competition with the goal of increasing the quality of the research system. Dedicated strategies and action plans are in place. Besides, collaboration and synergies with EU partners are part of virtually all major R&I policy initiatives, e.g. the internationalisation of Leading-Edge Clusters, Future Projects, and comparable networks ('Internationalisierung von Spitzenclustern, Zukunftsprojekten und vergleichbaren Netzwerken')¹¹².

4.2.2 RI roadmaps and ESFRI

The current roadmap for research infrastructures was presented by BMBF in April 2013 (BMBF, 2013b). BMBF has launched a new roadmap process for research infrastructure on 31 August 2015.¹¹³ Concepts can be submitted until January 2016. Minimum investment costs (German share) are €50m per project (€20m in social sciences) (BMBF, 2015e). Selected projects enter the national roadmap for research infrastructures ('Nationale Roadmap Forschungsinfrastrukturen') with a timeframe until 2018.

The current roadmap emphasizes infrastructure investment which will serve to explore the structure and dynamic of matter encompassing projects on elementary particles, condensed matter, nuclear physics, astrophysics, etc. (BMBF, 2014c). The roadmap contains as new infrastructure projects the Cherenkov Telescope Array,¹¹⁴ EU-OPENSREEN as a European infrastructure for chemical biology¹¹⁵ and IAGOS a infrastructure conducting long-term observations of atmospheric composition, aerosol and cloud particles¹¹⁶.

The European Strategy Forum on Research Infrastructures ESFRI is an important component of all decision making on research infrastructures. Germany is member of the legal entity of 1 of the 21 projects and 21 of the 29 landmarks within the ESFRI roadmap 2016. In Germany located projects on the roadmap include for example FAIR (Darmstadt) and European XFEL (Hamburg/Schleswig-Holstein)¹¹⁷. The Federal Government has invested €1.1b in large research equipment in 2014 and €1.2b in 2015 (BMBF, 2015c). The German Research Foundation DFG has provided €292.1m for research infrastructures between 2011 and 2013 or 3.7% of its total grants (DFG, 2015a). Data on financial commitments of Germany abroad are available for European Organisation for Nuclear Research (CERN) in Geneva (planned 2013: €176.8m, 2014: €180.1m) and the European Synchrotron Radiation Facility (ESRF) in Grenoble (planned 2013: €22.8m, 2014: €22.9m) (BMBF, 2014c) There is no indication that the budget commitments from Germany as part of ESFRI projects will not be fulfilled.

Germany had the largest number of both outgoing researchers as well as visiting researchers of research infrastructure that it operates funded by FP6 in 2011 and the number of visiting researchers is comparatively higher (ESFRI, 2012). The German

¹¹² <http://www.bmbf.de/de/25370.php> (2/2015)

¹¹³ <http://www.bmbf.de/press/3845.php> (8/2015)

¹¹⁴ <https://portal.cta-observatory.org/Pages/Home.aspx> (10/2015)

¹¹⁵ <http://www.eu-openscreen.eu/> (10/2015)

¹¹⁶ <http://www.iagos.org/> (10/2015)

¹¹⁷ http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=esfri (6/2016)

commitment to ESFRI and its further development is a central part of the strategy of the Federal Government for the European Research Area (ERA) published in 2014 (BMBF, 2014g). This strategy is accompanied by an action plan for international collaboration (BMBF, 2014a) emphasizing a “welcome culture” (‘Willkommenskultur’) for foreign researchers with easily available information, e.g. in welcome centres or online through EURAXESS, the European information portal. Other measures include Alexander von Humboldt-Professorships which provide German universities and research organisation with additional funds (up to €5m) to hire excellent researchers from abroad (BMBF, 2014a).

In sum, the German RI roadmap is well aligned with ESFRI priorities. National roadmap evaluations follow comprehensive guidelines developed by the German Council of Science and Humanities (‘Wissenschaftsrat’) and the German Federal Ministry of Education and Research (BMBF) in 2015: “Guidelines for outlining proposals for the National Roadmap for Research Infrastructures”¹¹⁸. Submitted research infrastructure proposals are assessed based on an external science-driven evaluation, which is carried out by the German Council of Science and Humanities (‘Wissenschaftsrat’), and an economic evaluation, which essentially consists of an external cost estimate of the submitted proposals for research infrastructures. Hence, the roadmap process for new research infrastructure which was announced on 31 August 2015 appears consistent and well structured.

4.3 International cooperation with third countries

Germany is actively collaborating with a large number of third countries. Among the industrial countries examples of collaborations include (BMBF, 2014c):

- Israel: German-Israeli-Foundation (‘Deutsch-Israelische Stiftung für wissenschaftliche Forschung und Entwicklung’, GIF)
- USA and Canada: More than 50 bilateral collaboration agreements, e.g. on battery technology or through the German-Canadian Co-operation on Kinetics and Mass Transport Optimisation in PEM Fuel Cells.
- Japan: Collaborations span more than 40 years and include for example a Junior Experts Exchange Program in natural sciences in which 200 junior researchers have participated so far.
- Australia: There exist 521 university collaboration agreements between Germany and Australia as well as joint research groups¹¹⁹
- South Korea: There exist roughly 30 collaborations between Fraunhofer and Max-Planck institutes with South Korean counterparts.

Germany has also increased its engagement for R&I with the so-called BRICS countries, Brazil, Russia, India, China and South Africa. Increased engagements with these countries are an explicit goal of the action plan of the Federal Government for international collaboration (BMBF, 2014a). Bilateral strategies with China and Africa have been launched recently and define concrete measures to strengthen international cooperation. In 2012 BMBF had invested €18.5m in collaborations with China, €10.1m with Russia, €8.7m with India and €2.5m with South Africa (BMBF, 2014c). More selective engagements include Tanzania, Egypt, Argentina, Columbia, Peru and Vietnam. BMBF has also initiated a website called “Research in Germany” as a central contact and information point for researchers from abroad.¹²⁰ These marketing efforts include the establishment of “German Houses for Science and Innovation” (‘Deutsche Wissenschafts- und Innovationshäuser’, DWIH) which organize promotion and networking events. They exist currently in New York, Sao Paulo, New Dehli, Cairo and Moscow (BMBF, 2014c).

¹¹⁸ https://www.bmbf.de/pub/Guidelines_for_outlining_proposals.pdf (08/2015)

¹¹⁹ <https://www.bmbf.de/de/australien-470.html> (10/2015)

¹²⁰ <http://www.research-in-germany.org/de/> (10/2015)

German policy on R&I collaboration with third countries emphasizes a balance between direct collaborations as well as multilateral EU and intergovernmental projects. The current strategy of the Federal Government for the European Research Area (ERA) published in 2014 (BMBF, 2014g) outlines the following measures:

- Strengthening the role of the Strategic Forum for International Science and Technology Cooperation (SFIC): The Federal Government supports the development of multi-annual roadmaps for important partner countries and regions which leverage Horizon 2020 and SFIC initiatives.
- Systematic, flexible support for multilateral scientific-technological collaboration projects ('Wissenschaftlich-technologische Zusammenarbeit', WTZ): The transfer of bilateral collaborations to multilateral collaborations including other EU member states and SFIC is envisioned.
- Extension of the internationalisation of Joint Programming Initiatives (JPIs)
- Targeted collaboration with third countries as part of Horizon 2020.
- Extension of the activities of German universities and the research organisations such as Helmholtz, Fraunhofer and Max-Planck which already have several partner institutes, collaboration partners and research centers in several third countries.

In conclusion, international collaboration with third countries has a long tradition within the German R&I system reflecting the high degree of internationalisation of the German economy. In particular the research organisations have reacted flexibly to research opportunities abroad and outside EU. Following new economic opportunities in BRICS countries, the focus of R&I collaboration activities has shifted as well. German priorities appear very much aligned with EU priorities. Besides, the German government wants to play an active role in EU-wide processes for extending collaborations with third countries.

4.4 An open labour market for researchers

4.4.1 Introduction

Germany has been classified as a country with regulated labour markets for researchers (JRC, 2013). This implies that national legislation or collective agreements determine processes related to hiring and promotions. Germany shares this institutional feature with Belgium, Cyprus, Greece, Spain, France, Italy, Malta and Portugal (JRC, 2013). The dominant form of employment for researchers in Germany is as civil servants ('Beamte') or public sector employees ('Angestellte').

Universities employed 662,076 employees in 2013, 56% of those employees are research or artistic personnel, 44% fulfil administrative, technical or similar jobs (BMBF, 2015c). Employment numbers include PhD students because they do not have student status in the German system. University employment has increased consistently: Total employment has increased by 7% between 2011 and 2013, research/artistic personnel has increase by 10% during the same time period¹²¹. Overall the growth of university employment in Germany is consistent and was not interrupted by the economic crisis of 2009. However, the increase in students has been stronger than the increase in university personnel. The ratio of students per full-time research/artistic personnel had its lowest level since 1995 in 2010 with 10.5 and has since increased to 11.2 in 2013¹²².

The Federal Government has agreed in September 2015 to reform the law for temporary employment in science ('Wissenschaftszeitvertragsgesetzes'). The previous version of the law was criticized for example by the union for education and science ('Gewerkschaft Erziehung und Wissenschaft') for inflating the number of short-term employment

¹²¹ Data from BMBF data portal, section "2.5.7 Higher education staff, habilitations", own calculations:
[http://www.datenportal.bmbf.de/portal/en/K257.html#chapters\(8/2015\)](http://www.datenportal.bmbf.de/portal/en/K257.html#chapters(8/2015))

¹²² BMBF data portal, section "2.5.7 Higher education staff, habilitations":
[http://www.datenportal.bmbf.de/portal/en/K257.html#chapters\(8/2015\)](http://www.datenportal.bmbf.de/portal/en/K257.html#chapters(8/2015))

contracts for junior researchers and reducing their opportunities for career planning.¹²³ The revised law ties the duration of the employment contact directly to the desired level of qualification, e.g. a PhD project, or third party grant ('Drittmittel') (see also section 4.4.4 of this report). Permanent tasks and related employment contracts are supposed to be separated from scientific or artistic training. Finally, the Federal Government is in the process of negotiating a broader initiative for predictable careers in science with Laender governments. The latter are primarily in charge of financing and regulating university education.

University student numbers have increased strongly. The total number of students enrolled in German universities reached a record high in the winter semester of 2015/2016 with almost 2.8m¹²⁴. This reflects two exceptions in the German education system in recent past. First, with the abolishment of the mandatory military service more students have entered universities. Second, the length of secondary education for obtaining the qualification to enrol at a university was shortened by one year. Hence, two generations of secondary school graduates entered universities at the same time. Not all Laender have agreed and implemented this change at the same time and the effect on student numbers has therefore been prolonged. However, the exceptional effects are about to expire. New enrolments have been 1.9% lower compared with previous years. The best student per research/artistic personnel ratios can be found in 2013 in Saxony (7.6), Mecklenburg-Vorpommern (8.4) and Thuringia (8.5); the highest in Nordrhein-Westfalen (14.3), Rheinland-Pfalz (14.0) and Hesse (13.3)¹²⁵.

52.1% of all university employees in 2013 was female and 37.7% of research/artistic personnel (BMBF, 2015c). While the female share of total university employees has increased slowly (e.g. 2000: 50.8%), the increase in female employees among scientific/artistic employees has been strong compared with 27.2% in 2000 or 35.2% in 2009 (see also section 4.4.5 of this report)¹²⁶.

4.4.2 Open, transparent and merit-based recruitment of researchers

The principle of transparent, open and merit-based recruiting is established in constitutional law, through the higher education laws of the Laender and a general Anti-Discrimination Act of 2006.

The hiring procedures at German universities for teachers and professors are traditionally competitive in nature. The Laender set the rules for hiring in higher education in Germany. They are increasingly transferring the appointment rights for new staff to the universities or public research organisations. Laender higher education laws guarantee the openness of recruiting procedures including advertising. As a rule, openings are announced through public advertising nationally and internationally. The latter can be mandatory or contingent on the importance of the respective position.

The evaluation process of applications typically includes external experts in committees which compare applications. It is unlikely in the German system that universities would hire their own PhD students after they have received their doctorate. This rule is supposed to ensure the openness and transparency of hiring decisions.

The Federal Government has enacted the Academic Freedom Act in 2012 which gives higher education institutions more autonomy in their recruiting decisions including the use of third-party funds for hiring top researchers. Public research organisations have also significant autonomy in their hiring decisions. Taking also into account that the

¹²³ <http://www.gew.de/wissenschaft/wissenschaftszeitvertragsgesetz/> (10/2015)

¹²⁴ https://www.destatis.de/DE/PresseService/Presse/Pressemitteilungen/2015/11/PD15_432_213.html (1/2016)

¹²⁵ BMBF data portal, section "2.5.7 Higher education staff, habilitations":

<http://www.datenportal.bmbf.de/portal/en/K257.html#chapters> (8/2015)

¹²⁶ Data from BMBF data portal, section "2.5.7 Higher education staff, habilitations", own calculations:

<http://www.datenportal.bmbf.de/portal/en/K257.html#chapters> (8/2015)

individual Laender enact legislation on higher education implies that the recruiting landscape cannot be fully homogeneous throughout Germany.

Traditionally, junior faculty would go through a multi-year habilitation stage after their PhD. This system is increasingly replaced or modified emphasizing the value of scientific journal publications. Some universities allow habilitations which are collections of scientific journal publications, i.e. not a separate research outcome. Many universities specify in their job advertisements for full professors that candidates do not require a habilitation if they have an equivalent journal publication record. Accordingly, the number of habilitations in Germany has been declining to 1,567 in 2013 compared with 2,128 in 2000¹²⁷. The Laender have changed legislation to introduce a tenure track system in which junior faculty can enter as "Junior Professor" on a fixed term contract which can be transferred into a permanent university professor position. The tenure track model is supposed to make academic careers faster and more transparent. It is fairly similar to the Assistant Professor tenure track system for junior faculty positions in many other countries.

In 2013 Germany had 45,013 professors¹²⁸, 1,597 were junior professors (Statistisches Bundesamt, 2014). Based on employment statistics an average profile of junior professors in Germany can be drawn (Statistisches Bundesamt, 2014):

- 40% of junior professors are female (compared with 21% of all professors)
- Junior professors are on average 36,7 years old (total: 50.6)
- Almost all junior professors (97%) have temporary contracts (total: 14%) and work full time (3% work part time compared with 8% of all professors)
- 81% of junior professor positions are funded by their respective universities, 10% by grants from government sources, 7% by private grants and the rest by student fees or other sources. For comparison, 92% of all professor positions are funded by their respective universities, 3% by grants from government sources and 2% by private grants.

In sum, it is not unusual in an international context to have temporary tenure track positions for junior faculty. It is noteworthy that comparatively more junior professor positions originate from competitive grants.

Naturally, the demand for new faculty varies by field. Nevertheless, 17% of all professors in Germany (7,659 in total) are 60 years and older in 2013 (Statistisches Bundesamt, 2014). Their positions will require retirement replacement hiring in the medium to short term. This is a positive structural feature for the career opportunities of young researchers in Germany. A similarly positive sign is the increase in junior professor positions. The number of junior professors has increased by 361 positions or 29% between 2010 and 2013 compared with an increase of 9% for all professor positions (Statistisches Bundesamt, 2011). There is no indication that government budget constraints have restricted the hiring of young researchers.

Focussing on the international labour market, the Expert Commission on Research and Innovation provides an in-depth analysis of international flows of scientific personnel to and from Germany in its evaluation report 2014 (EFI, 2014): Roughly 2.47m employees worked in scientific professions in 2010 in Germany. Roughly 135,000 of those employees were immigrants. The share of foreigners in scientific professions is therefore significantly smaller (5.5%) than in non-scientific professions (10.8%). Among researchers with scientific publications 19,521 researchers have newly moved to Germany between 1996 und 2011 compared with 23,460 who have left Germany. The researchers leaving Germany are comparatively more publication productive and return

¹²⁷ BMBF data portal, section "2.5.7 Higher education staff, habilitations":
[http://www.datenportal.bmbf.de/portal/en/K257.html#chapters\(8/2015\)>](http://www.datenportal.bmbf.de/portal/en/K257.html#chapters(8/2015)>)

¹²⁸ The total number is based on professors with payment scales W2, W3, C2, C3, C4, junior professors as well as a small group of full-time guest professors (566).

rates to Germany are lower compared with other countries. EFI (2014) recommends that excellent research conditions and increased flexibility in teaching loads as well as eased administrative burdens would allow German universities to attract and retain excellent researchers in international competition.

In particular the Heisenberg programme¹²⁹ and the Emmy Noether programme¹³⁰ of the German science foundation (DFG) contain grant elements encouraging researchers abroad to return to Germany. Both programmes provide scholarships for excellent researchers. Additionally, the Heisenberg programme includes the opportunity to fund a subsequent Heisenberg professorship. Besides, the initiative for excellence ('Exzellenzinitiative') contains activities which are supposed to attract researchers from abroad to German universities (EFI, 2014). Besides, DAAD sponsors the German Academic International Network (GAIN) which is primarily designed to provide information for German scientists in North America.¹³¹ GAIN provides information on topics such as open positions or changes to R&I policies in Germany in digital form. Besides, it sponsors an annual meeting in the US. GAIN has currently roughly 5,000 registered members.

In conclusion, there are no obstacles to open, transparent and merit based recruitment of international researchers in Germany. Barriers can emerge from differences in language or the institutional backgrounds of researchers from abroad. The Federal Government has announced an action plan for international co-operation in 2014 ('Aktionsplan Internationale Kooperation', BMBF, 2014a). The action plan of the Federal Government includes elements to lower such barriers. It envisions a "welcome culture" ('Willkommenskultur) which provides information, e.g. in welcome centres or online through EURAXESS, the European information portal. Other measures include Alexander von Humboldt-Professorships which provide German universities and research organisation with additional funds (up to €5m) to hire excellent researchers from abroad (BMBF, 2014a).

4.4.3 Access to and portability of grants

Access to grants and scholarships depends on the programme. Scholarships are generally advertised internationally and many programmes target international recipients, e.g. through the German Academic Exchange Service (DAAD), the German Research Foundation (DFG) or the Alexander von Humboldt Foundation (AvH). Practical consideration can limit access to certain scholarships such as when they require language skills, e.g. especially in German, or the recognition of professional skills or diplomas. The latter has become easier since 2012 with the enactment of a law for simplifying such recognition procedures ('Gesetz über die Feststellung der Gleichwertigkeit von Berufsqualifikationen, Berufsqualifikationsfeststellungsgesetz - BQFG').¹³² 13,344 recognition applications were processed in 2013 with a positive recognition rate of almost 75% (BMBF, 2015a). Improving international recognition procedures even further is also part of the action plan of the Federal Government for the future (BMBF, 2014a).

Access to apply for grants for researchers affiliated in foreign institutions follows different rules. DFG defines as a general rule that every researcher in Germany or affiliated with a German research institute abroad can apply (if her/his scientific education ends with a PhD)¹³³. Researcher from outside Germany can be funded in

¹²⁹ <http://www.dfg.de/foerderung/programme/einzelfoerderung/heisenberg/index.html> (8/2015)

¹³⁰ http://www.dfg.de/foerderung/programme/einzelfoerderung/emmy_noether/ (8/2015)

¹³¹ http://www.bmbf.de/de/908.php?pk_campaign=26-08-2015-+Newsletter+-+BMBF+-+Pressemitteilungen&pk_kwd=http%3A%2F%2Fwww.bmbf.de%2Fde%2F908.php (8/2015)

¹³² <http://www.gesetze-im-internet.de/bundesrecht/bqfg/gesamt.pdf> (2/2015)

¹³³

http://www.dfg.de/foerderung/antragstellung_begutachtung_entscheidung/antragstellende/antragstellung/index.html#micr013339225 (10/2015)

collaborative research projects (Money follows Cooperation line) (DFG, 2009). Further exceptions exist for cross-border access for researchers from Germany, Austria and Switzerland (D-A-CH). Researchers from research institutions in these countries can apply for funding for border crossing projects in one country only (Lead Agency Principle)¹³⁴.

DFG has agreed to the principle of "Money Follows Researcher" within D-A-CH in 2003 and within EUROHORCs (European Heads of Research Councils) in 2004 (DFG, 2009). This implies that grants for research can be transferred to other countries with few conditions.

4.4.4 Doctoral training

The German higher education system graduated 2.7 new doctorate students per 1,000 25-34 year olds in the population in 2012 (European Commission, 2015c). This ratio has been relatively stable in recent years (2011: 2.8) and is significantly above the average of EU-28 (1.8). Germany ranks significantly below EU-28 averages when it comes to attracting non-EU doctoral students. Only 11.3% of doctoral students in Germany come from outside of the EU compared to 25.5% in EU-28 in 2012 (European Commission, 2015c).

The system of doctoral training in Germany is heterogeneous. First, the Laender are responsible for setting rules in education as a principle established in the German constitution. Second, within Laender laws universities and sometimes even individual faculties have agency in deciding about structures, rules and procedures for acquiring a PhD ('Prüfungsordnung, Promotionsordnung'). Structural training is not automatically required for earning a PhD in Germany. Students can receive a doctoral degree at a chair ('Lehrstuhl').

The role of the Federal Government is limited. Impulses in the direction of more structured doctoral programs stem from funding schemes for structured doctoral training programmes provided by the DFG (since 1990) and as part of the joint Initiative for Excellence of Federal Government and Laender (since 2006). The resulting doctoral programmes are typically referred to as graduate schools or research training schools ('Graduiertenschulen/Graduiertenkollege'). DFG has provided €384.1m for the establishment of these PhD schools between 2008 and 2010 as well as an additional €138.2m through the Initiative for Excellence in the same time period (DFG, 2012). This funding has resulted in 237 PhD schools through the former and 39 through the latter (DFG, 2012). In addition, Max Planck society has introduced International Max Planck Research Schools (IMPRS) in 2000 as structured doctoral programmes. There are currently 60 IMPRS.

The PhD schools receiving funding through DFG or the Initiative for Excellence do not follow a fully standardized model. Concepts are individually developed by universities and subsequently evaluated through DFG and the Science Council ('Wissenschaftsrat'). The evaluation is based on four criteria: Quality of the proposed research programme (relevance, novelty, appropriateness, coherence, etc.), quality of the participating researchers (credentials and experience with training), quality of the qualification and supervision strategy (e.g. supervision structures) as well as the fit with the environment¹³⁵. The best concepts receive funding.

The competition for funding of PhD schools through the Initiative for Excellence has been a major driver for innovative PhD training schemes. The innovativeness of the proposed PhD school was an evaluation criterion. At the same time, the diversity of proposals left room for creative proposals which fit the context of the topic and location.

¹³⁴ http://www.dfg.de/download/pdf/foerderung/programme/antragstellung_oesterreich_schweiz/antragstellerhinweise.pdf (10/2015)

¹³⁵ http://www.dfg.de/formulare/1_304/1_304_en.pdf (8/2015)

Many universities have extended opportunities for doctoral studies in which the extensions are typically structured PhD programs. Doctoral study regulations ('Promotionsordnung') are largely organized at the faculty level, e.g. at the Humboldt University of Berlin or the Ludwig Maximilian University (LMU) of Munich. The former has grouped promotion rules, e.g. all natural science fields, while the latter lists 204 rules by department and topic. Both universities emphasize their structured doctoral programs of which Humboldt university has more than 40 and LMU 36. Several of these doctoral programs at both universities originate from competitive grants provided by DFG, as part of the initiative for excellence ('Exzellenzinitiative') or in collaboration with the Max Planck society. Humboldt University emphasizes the advantages of a structured program and the opportunities for interaction with other PhD students and supervisors. LMU presents the opportunities for an individual, unstructured doctoral study but also discusses the challenges. In sum, both leading universities seem to have shifted the focus to structured doctoral programs.

The Federal Government has agreed in September 2015 to reform the law for temporary employment in science ('Wissenschaftszeitvertragsgesetz') (see also section 4.4.1 of this report)¹³⁶. As a consequence, employment contracts for PhD students should cover the length of their PhD projects. The agreement also includes the creation of a dedicated statistical basis covering PhD students ('Promovierendenstatistik'). These statistics are supposed to provide a more precise empirical basis for policy making on the topic.

4.4.5 Gender equality and gender mainstreaming in research

The German constitution guarantees gender equality and requires that the government removes existing disparities (Grundgesetz, GG Article 3). Within the R&I context, German Research Foundation (DFG) declares explicitly in article 1 of its statutes: "The DFG promotes equality between women and men in science and academia" (DFG, 2014b). The Joint Science Conference (GWK) collects and publishes data annually on equal opportunity in science and research. It highlights the following major trends in its 2014 report (GWK, 2014):

- The share of women at universities has been increasing between 2003 and 2012 at all levels, from 48.2% to 49.5% among new university students, from 49.4% to 51.0% among university graduates, from 37.9% to 45.4% among new doctoral degrees, from 22.0% to 27.0% among new habilitation degrees, among 31.2% to 38.0% among junior professors and from 12.8% to 20.4% among professors.
- The share of women increases slowly and growth rates become weaker at higher career and salary levels.
- Female professors are comparatively less likely to hold permanent contracts and more likely to work part-time.
- The share of women is also increasing throughout the recruiting process. 25.5% of applicants for professor positions were female in 2013 (2004: 17.5%), 30.1% of applicants receiving a call ('Berufung') were female (2004: 19.1%) and 29.9% of hired professors were female (2004: 20.3%).
- The share of women in leadership positions is also increasing. Women held 22.5% of leadership positions at universities (2004: 15.8%) in 2013 and 13.5% at research organisations (FhG, HGF, MPG, WGL) (2004: 6.9%).

Among the most comprehensive measures for increasing the gender equality among researchers in Germany has been the announcement of Research-Oriented Standards on Gender Equality ('Forschungsorientierte Gleichstellungsstandards der DFG') of the German Research Foundation (DFG) in 2008 for its members (DFG, 2008). The goal of the standard was a significant increase of the share of women in science and humanities. The standard also includes the definition of target shares of female employment for each career level. Upon reviewing the standard in 2013 DFG identified improvements but the

¹³⁶ <https://www.bmbf.de/de/bessere-bedingungen-fuer-den-wissenschaftlichen-nachwuchs-1049.html> (1/2016)

improvements remained below expectations. As a consequence, the implementation is now more closely connected with research grants, i.e. grant applications are required to detail how many female scientists will participate at which career level (EFI, 2014). Besides, universities are required to provide annual reports on the quantitative status of gender equality at their institutions to DFG¹³⁷.

Moreover, Laender and Federal Government have extended a dedicated programme for female professors ('Professorinnenprogramm') in 2015 until 2017 after a positive evaluation of the original funding period which started in 2008. The program is based on a competition of gender equality programs among universities and can provide funding for five years for female professors. The program had an initial budget of €300m and has funded 351 professor positions as of February 2015¹³⁸.

DFG also provides indicators for gender equality in research grants through its equal opportunity monitoring report ('Chancengleichheits-Monitoring'). The most recent report provides data for 2014 (DFG, 2014a, 2015c): Female scientists accounted for 23,5% of individual grant applications in 2014 (2010: 21.0%) with strong differences between fields. In social sciences and humanities female scientists make up 34,5% of applications in 2013 with an increasing trend (2011: 32,2%) while in natural sciences the account for only 14,7% in 2014 with an much slower increasing trend (2010 14,0%). Among granted, individual projects female scientists had a success rate of 32,2% in 2014, which is lower compared with male applicants (34,8%) and slightly lower than in previous years (2011: female 35,7%, male 36,3%).

With regard to decision making on grants, the share of female reviewers for grant applications is increasing to 15.8 % in 2014 from 13.7% in 2011 (DFG, 2015c). The same is true for the review boards of the DFG ('Fachkollegien') which vote on funding recommendations for particular projects. The share of female scientists on these committees ranges from 35.6% in social sciences in 2013 to 10% in engineering (DFG, 2014a).

Regarding individual measures supporting gender equality in research programmes, the predominant form of support for female researches is to reduce frictions from managing family planning and a scientific career simultaneously. Many programs for individual grants (e.g. the Emmy Noether program) provide flexibility for maternity leave or the support of ailing relatives. This flexibility can have the form of project extensions or temporary supplement to support project management functions¹³⁹. Besides, scholarships often times include special allowances for child support.¹⁴⁰ DFG supported coordinated programs, such as Research Training Groups/graduate schools ('Graduiertenkolleg') can receive extra funds for PhD students who are pregnant or have children¹⁴¹.

¹³⁷

http://www.dfg.de/foerderung/grundlagen_rahmenbedingungen/chancengleichheit/forschungsorientierte_standards/jaehrliche_abfrage/index.html (8/2015)

¹³⁸ <http://www.bmbf.de/de/494.php> (8/2015)

¹³⁹

http://www.dfg.de/foerderung/grundlagen_rahmenbedingungen/chancengleichheit/massnahmen/sachbeihilfen_einzelfoerderung/index.html (8/2015)

¹⁴⁰ http://www.dfg.de/formulare/1_04/1_04_de.pdf (8/2015)

¹⁴¹ http://www.dfg.de/formulare/1_42/1_42.pdf (8/2015)

4.5 Optimal circulation and Open Access to scientific knowledge

4.5.1 e-Infrastructures and researchers electronic identity

The Federal Government has announced its Digital Agenda 2014-2017 in 2014 (BMWi, 2014a). In the agenda the Federal Government highlights its objectives and priorities:

- Digital networks as drivers for economic growth and employment, with a particular focus on manufacturing and logistics as well as on small and medium sized companies.
- Access and participation, especially through broadband networks and childhood education.
- Confident and secure usage, particularly through secure communications and infrastructures.

The agenda covers a broader set of initiatives, e.g. innovative public administration, but the most relevant aspect for this report is under the heading of "Education, science, research, culture and media:" There are six priorities defined within this subject:

- Accelerating the digital transformation in science:
Within this area the development of a digital transformation strategy is planned which facilitates the flow of information between archives, libraries, research and publication. The Federal Government also wants to support strategic projects which connect research databases, repositories and virtual research environments. The process is accompanied by the establishment of a German Council for Scientific Information Infrastructures ('Rat fuer Informationsinfrastrukturen', RfII) as an advisory committee and for the development of recommendations. This council has been established in November 2014 as a shared initiative of Federal and Laender governments. It consists of eight representatives of scientific users, eight representatives of organisations such as libraries and archives, four representatives of public life and four representatives of Federal and Laender governments¹⁴².
- Safeguarding access to knowledge as a basis for innovation:
The Federal Government plans a comprehensive open access strategy and an increase in the ease with which funded research publications and data can be accessed. Further, the introduction of a copyright limitation for education and science is planned.
- Education campaign for the digital knowledge society:
The Federal Government will develop a digital learning strategy together with the Laender which are responsible for decisions on education. Further, the Federal Government wants to identify and implement training needs for initial training, further training and continuing education. This is supported at the vocational school level through the programme Digital Media in Vocational Education and Training" ('Digitale Medien in der beruflichen Bildung')¹⁴³ as well as at the university level through the Digitisation University Forum ('Hochschulforum Digitalisierung')¹⁴⁴.
- Exploiting digitisation's potential for innovation:
In this area the Federal Government wants to integrate the opportunities of its broader High Tech Strategy with the areas of IT security research, microelectronics and service research. Special priority is also given to opportunities originating from big data with the establishment of two centres of excellence for big data in Berlin and Dresden. They are supposed to provide innovation support in business, science and health services. The Federal Government also wants to establish Germany as a leader in high-performance computing and strengthen research on digitisation in medicine.

¹⁴² <http://www.rfii.de/?wpdmdl=1929> (9/2015)

¹⁴³ <http://www.bmbf.de/de/16684.php> (9/2015)

¹⁴⁴ <http://hochschulforumdigitalisierung.de/> (9/2015)

- Understanding the digital transformation through research:
The Federal Government wants to increase research into privacy protection and the right to privacy as well as self-determination and transparency. For this purpose it envisions interdisciplinary studies which focus on topics such as the coevolution of technology, work, society and skills. There are plans for a publicly funded research institute which will investigate ethical, legal, economic and participatory aspects of the internet and digitisation.
- Culture and media:
The Federal Government plans a German Digital Library. In a broader sense it wants to increase the digitisation of cultural assets and their diffusion while addressing needs for legal frameworks and copyright legislation.

It is also noteworthy that Germany's Digital Agenda 2014-2017 incorporates explicitly European and international dimensions (BMW, 2014a). The integration of German and European digital agendas are especially prioritized in governance and legal frameworks as well as in the involvement of Germany in European decision making committees.

As part of the Digital Agenda process, BMBF has established an interdisciplinary expert platform on the topic of digitalisation in education and science ('IT-Gipfel-Plattform Digitalisierung in Bildung und Wissenschaft') in September 2015.¹⁴⁵ The platform consists of experts from science, business, politics, unions and associations. Its task is to develop solutions and projects on a range of issues such as Open Data and Big Data in science and education.

The Digital Agenda process is accompanied by monitoring reports. The latest monitoring report ('Monitoring-Report Digitale Wirtschaft 2014' was published in December 2014 (BMW, 2014b). The monitoring report takes a broader perspective on the state of the digital economy in Germany as a whole not just R&I related topics. The report places Germany in fifth spot in an international comparison on the overall performance, significantly behind the United States as the leading digital economy. The German digital performance is close to several other European countries, e.g. Denmark or Finland, as well as China, and behind but within reach of South Korea, the UK and Japan. With regard to R&I topics the monitoring report identifies also potential for improvement (BMW, 2014b):

- The penetration of optical fibre cable in the broadband network infrastructure should be improved in Germany. Germany ranks currently last in Europe with a penetration rate of 1%. There are ongoing political discussions that the Federal Government could increase its investment into the digital network as part of an additional spending bill directed at infrastructure improvements (digital or physical).
- Innovation should be encouraged which facilitates the digital integration of supply chains such as between suppliers, manufacturers and customers. The performance, efficiency and flexibility potentials of such integrations are sometimes referred to as "Industry 4.0". Such innovations are often times improvements of business processes and have a large performance potential especially for SMEs in Germany ('Mittelstand').
- The potentials of the previous point are best reached if education and training systems become more interdisciplinary in nature. Skillsets which will be in high demand are not just better along the dimensions of technology and mathematics but will require also management skills as well as international expertise.
- Regulatory steps, e.g. on data protection, should be unified across Europe and embedded in global regulatory systems.

¹⁴⁵ <https://www.bmbf.de/presse/digitalisierung-in-bildung-wissenschaft-und-forschung-gestalten-1245.html> (9/2015)

The Expert Commission on Research and Innovation (EFI) highlights in its 2015 report the challenges of balancing innovation potentials from digital data with data protection concerns (EFI, 2015). The report asks for more clarity in how government will strike this balance. Among other things, EFI recommends that government should be a role model for how trust can be built based on verifiable data security rules and advocates EU wide principles, e.g. on the applicability of data protection standards if processing occurs in other countries. Besides, EFI recommends open standards for digital formats which involve many partners who can identify security concerns quickly and help closing them. More generally, EFI recommends setting specific, transparent implementation plans for the goals expressed in the Digital Agenda 2014-2017.

Similarly, the working group responsible for consulting the Federal Ministry for Economics (BMW) on issues related to Industry 4.0 as part of the SME advisory board ('Arbeitsgruppe Industrie 4.0 im Mittelstandsbeirat des BMW') emphasizes educational, broadband, technological, financial and marketing instruments for realizing the economic potentials from Industry 4.0 for SMEs in Germany in September 2015¹⁴⁶. Among the Industry 4.0 instruments suggested are dedicated training and university education, targeted, inclusive immigration, reference implementations, favourable tax incentives and depreciation rules as well as advertising the term "Industrie 4.0".

In September 2015 the Federal Government has initiated a tender for the foundation of a German Internet Institute ('Deutsches Internet-Institut')¹⁴⁷. The tender is directed at universities, non-university research organisations and collaborations of both. The ultimate goal is to establish an institute which is dedicated to research and technology transfer on all topics related to digitalisation, e.g. data security or political, legal, economic consequences.

With regard to existing instruments in place for identity validation and personal data use, Germany has an electronic ID card. This card allows electronic authentication and electronic signature. Hence, it enables secure identification via the internet. The card contains biometric features which limit the risk of identity theft. The card is intended to facilitate secure and trusted business transactions online for e-government and e-business. Technological boundaries and security concerns prevent a broader use of electronic IDs. Digital Author IDs are for example currently only in a discussion stage, similarly to a unified European ID card in projects such as BIOP@SS project¹⁴⁸.

4.5.2 Open Access to publications and data

Open access to publications and data is an explicit priority of the Digital Agenda 2014-2017 of the Federal Government (BMW, 2014a). Most Open Access initiatives in Germany are traced back to the Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities ('Berliner Erklärung über den offenen Zugang zu wissenschaftlichem Wissen') of 2003.¹⁴⁹ The declaration was introduced by the Max Planck Society but signed by currently 480 institutions which commit themselves to Open Access. The Alliance of Science Organisations in Germany¹⁵⁰ is actively promoting Open Access through its Priority Initiative "Digital Information"¹⁵¹. German research

¹⁴⁶ <http://www.bmw.de/BMW/Redaktion/PDF/F/forderungen-arbeitskreis-industrie-4-0-mittelstandsbeirat-bmw.property=pdf.bereich=bmw.sprache=de.rwb=true.pdf> (1/2016)

¹⁴⁷ <https://www.bmbf.de/de/startschuss-fuer-das-neue-internet-institut-1336.html> (1/2016)

¹⁴⁸ <http://www.biopass.eu/> (9/2015)

¹⁴⁹ <http://openaccess.mpg.de/Berliner-Erklaerung> (9/2015)

¹⁵⁰ The members of the alliance are Alexander von Humboldt Foundation, the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation), the Fraunhofer-Gesellschaft, the German Academic Exchange Service, the German Council of Science and Humanities (Wissenschaftsrat), the German National Academy of Sciences Leopoldina, the German Rectors' Conference, the Helmholtz Association of German Research Centres, the Leibniz Association, and the Max Planck Society (<link>)

¹⁵¹ <http://www.allianzinitiative.de/en/core-activities/open-access.html> (9/2015)

organisations are also active as members of Science Europe which has recently announced its Principles for the transition to Open Access for research publications¹⁵².

The Federal Ministry of the Interior ('Bundesministerium des Inneren', BMI) has put forward a national action plan of the Federal Government for implementing the Open-Data-Charta of G8 in November 2014 (BMI, 2014). Part of the action plan is to open personal, non-sensitive data collected by the government for scientific analysis. This progress has been welcomed by R&I actors such as the Expert Commission on Research and Innovation (EFI, 2015).

The most recent discussion on Open Access in Germany follows legal changes of copyright law in 2013. The new law introduces a Secondary Exploitation Right ('Zweitverwertungsrecht') for authors¹⁵³. The essence of the law is that scientific authors will have the right to publish their research again one year after they have initially published it in scientific journals and presumably transferred all exploitation rights to a publishing house. Hence, the transfer of copyrights in an author contract becomes irrelevant after one year. While the law is generally in line with the goal of Open Access, it has been criticized especially from research organisation for its exceptions¹⁵⁴. Most of the criticism stems from the condition that the law will only apply to results of teaching or research with at least half of its funding from public project funding or at an institutionally funded extramural research institution. This share can be hardly determined in practice and excludes university research unless it is financed by public third-party funding ('Drittmittel').

The Expert Commission on Research and Innovation (EFI, 2015) sees room for more reform of copyright laws related to digital innovation (see also section 2.2.1 of this report). In general, the Commission recommends changes and simplifications in copyright laws. Among other things, it suggests permitting redesigns of digital content for non-commercial use to encourage user innovation. Besides, EFI (2015) recommend the introduction of violation alerts preceding the current practice of costly, formal warnings. Finally, the Commission weighs a general exemption of scientific findings from copyright laws to provide broad access. Such exemptions could be accompanied by compulsory compensation rules.

Open Access has been typically classified in three types: Gold, green and hybrid.¹⁵⁵ Archambault et al. (2014) present a set of indicators for the diffusion of Open Access in various countries. This study provides indicators for the share and type of Open Access publications between 2008 and 2013. Out of 66,268 scientific papers sampled for Germany, 50.9% were available through Open Access between 2008 and 2013. This share is almost equal to the average EU-28 (51.3%). 7.6% of articles in Germany were available through Gold Open Access which is slightly below EU-28 average (8.6%). 11.4% of articles in Germany were available in Green Open Access formats and 33.2% in other Open Access formats. This share is above EU-28 average of 9.4% for Green

¹⁵² http://www.scienceurope.org/uploads/Public%20documents%20and%20speeches/SE_OA_Pos_Statement.pdf (9/2015)

¹⁵³ http://www.bundestag.de/dokumente/textarchiv/2013/45176990_kw24_pa_recht_urheberrecht/212712 (9/2015)

¹⁵⁴ <http://www.helmholtz.de/artikel/zweitverwertungsrecht-forschungsorganisationen-kritisieren-einschraenkungen-1560/> (9/2015)

¹⁵⁵ Gold open access (open access publishing): payment of publication costs is shifted from readers (via subscriptions) to authors. These costs are usually borne by the university or research institute to which the researcher is affiliated, or by the funding agency supporting the research.

Green open access (self-archiving): the published article or the final peer-reviewed manuscript is archived by the researcher in an online repository before, after or alongside its publication. Access to this article is often delayed ('embargo period') at the request of the publisher so that subscribers retain an added benefit. The green access model allows for certain variations: the length of the embargo period and the version that may be archived at different moments in time vary, e.g. depending on the agreements between publishers and authors.

Hybrid open access refers to a publishing model in which subscription-based journals allow authors to make individual articles open access on payment of an article publication fee.

Open Access and slightly below 34.9% for other Open Access formats. In sum, Open Access patterns in Germany are well aligned with the rest of Europe.

A more recent variant of Open Access is the ID/OA mandate (i.e. Immediate deposit/Optional Access)¹⁵⁶ or also called the "Liege Model." There is no information available on the usage of this model in Germany.

¹⁵⁶ The model implies that upon acceptance for publication authors are required to upload the publication to the repository of their institution. The access decision (closed or open) is left to the authors but they are strongly encouraged to make the full text available in an open format quickly (<[link](#)>).

5. Framework conditions for R&I and Science-Business cooperation

5.1 General policy environment for business

The World Bank compiles an annual report on “Doing Business” which provides comparable data across countries for regulations which enhance or constrain business activity¹⁵⁷. Overall Germany ranks in 15th place out of a 189 countries study according to the most recent report “Doing Business 2016” (World Bank, 2015). The report puts Germany close but behind the other EU innovation leader countries Sweden (8th rank), Finland (10th rank), UK (6th rank) and Denmark (3rd rank).

The overall rank consists of 11 areas which determine the ease of doing business: starting a business, dealing with construction permits, getting electricity, registering property, getting credit, protecting minority investors, paying taxes, trading across borders, enforcing contracts and resolving insolvency. Germany is ranked favourably within the areas of dealing with construction permits (13th rank), getting electricity (3rd rank) and resolving insolvency (3rd rank) (World Bank, 2015). The largest deficits emerge in the areas of starting a business (107th rank), registering property (62nd rank) and paying taxes (72nd rank).

Apart from regulations, risk perceptions can also affect economic activity. The Global Entrepreneurship Monitor compares the risk of failure perception in multiple countries. Risk of failure is defined in this report as “Percentage of 18-64 population with positive perceived opportunities who indicate that fear of failure would prevent them from setting up a business”¹⁵⁸. This risk of failure perception among potential entrepreneurs is at 40% in 2014 and only slightly down from 2011 (42%). At this level the perception in Germany is almost identical to EU-28 average (40.7%), close to Denmark (41%) but higher than in Sweden (36.5%) and Finland (36.8%), among the other innovation leader member states as defined by the EU Innovation Scoreboard 2014 (Global Entrepreneurship Monitor, 2015). For comparison, the value for the United States is 29.7%.

The reorganisation of companies in Germany is governed by the insolvency law (‘Insolvenzordnung,’ InsO) which stems from 1999¹⁵⁹. The law provides the opportunity to find flexible and economical solutions between creditors and debtors to preserve the company. Both parties can take the initiative to file for insolvency in court. In Germany, more than 80% of filings originate from the indebted firm (Egeln et al., 2010). The court appoints an insolvency administrator (‘Insolvenzverwalter’) to organize the insolvency process. The insolvency law provides the opportunity to design an insolvency plan (‘Insolvenzplan’) which lays out the current state of the firm but also what steps would be necessary to preserve it¹⁶⁰. All parties need to agree on the plan.

In principle the insolvency plan should make it more likely to preserve the firm. A recent study of BMWi from 2010 finds, however, that the option of an insolvency plan is rarely used or ineffective especially for young firms (Egeln et al., 2010). The study cites three primary reasons: insolvent companies are not aware of the opportunities from an insolvency plan, insolvency administrators have little incentive to invest time into developing an insolvency plan and judges have little economic expertise to evaluate it.

¹⁵⁷ <http://www.doingbusiness.org/reports/global-reports/doing-business-2015> (10/2015)

¹⁵⁸ <http://www.gemconsortium.org/docs/download/414> (2/2015)

¹⁵⁹ <http://www.gesetze-im-internet.de/insol/> (12/2014)

¹⁶⁰

https://www.justiz.nrw.de/JM/online_verfahren_projekte/projekte_fuer_partner_der_justiz/infos_inso/insolvenzen_infos/info_intro05/index.php (10/2015)

5.2 Young innovative companies and start-ups

The creation of new firms is an important channel through which new technologies, materials and processes lead to economic growth and job creation. This vision is largely shared by federal and Laender governments in Germany as evidenced in the national report on research and innovation ('Bundesbericht Forschung und Innovation', BMBF, 2014c). The overall entrepreneurship environment in Germany has improved in 2014 with 915,000 newly founded firms; a plus of 47,000 compared to 2013 (KfW, 2015). The KfW Start-up Monitor ('KfW Gruendungsmonitor') also reveals that more entrepreneurs in Germany start their firms based on opportunity discovery (48%) not because of necessity.

Entrepreneurship propensity in Germany is comparatively low in an international context. This is often times explained with the promising career opportunities in existing firms and hurdles for obtaining early stage funding (BMBF, 2014c). The policy portfolio in Germany aims at addressing all stages of the entrepreneurship process from science with the fostering of an entrepreneurship culture (EXIST), idea generation (various competitions), counselling and advice (university incubators and entrepreneurship offices), early stage funding (HTGF), creation of professional networks and advice (INVEST) as well as funding for business development (ERP-Startfonds). The most prominent entrepreneurship initiatives of the Federal Government include (see also section 3.5 of this report) (BMBF, 2014c):

- EXIST – Existenzgruendung aus der Wissenschaft¹⁶¹:
The programme of BMWi was initiated in 1998 and is co-financed by the European Social Fund (ESF). It provides a range of instruments to entrepreneurs from academia. As part of the broader programme, EXIST wants to foster an entrepreneurial culture in universities through the competition "EXIST-Gruendungskultur." 120 universities have developed and submitted concepts, from which 22 universities with the most promising concepts have been chosen and receive support for the implementation of their concepts. "EXIST-Gruenderstipendium" provides yearlong scholarships for potential entrepreneurs from universities and research organisations. The scholarship is supposed to facilitate the pre-entrepreneurship stage in which potential founders develop business plans. Roughly 150 scholarships are granted annually. "EXIST-Forschungstransfer" provides bridge funding for the development of technologically advanced research projects into commercial applications. It has resulted in 90 new firms since 2007.
EXIST has been reformed in December 2014 with increases in available funds¹⁶². Scholarships (EXIST-Gruenderstipendium) increase by 25% and the included funds for investments cannot reach €30,000 instead of €17,000. Within EXIST-Forschungstransfer available investments in high tech projects increase from €70,000 to €250,000.
- High-tech Start-Up Fund ('High-Tech Gruenderfonds', HTGF)¹⁶³:
HTGF was initiated in 2005 in collaboration of BMWi, government controlled banking group KfW and industrial partners with an investment endowment of €272m. The purpose of HTGF is to address particularly funding needs of new firms for which it can be extremely difficult to attract lender or private equity investors. HTGF provides equity financing of up to €500,000 for newly founded technology firms. HTGF provides also access to a network of certified coaches and venture capital investors for future investment rounds. HGTF has 330 investments in its portfolio (March 2014) and has provided support for investments of third parties of roughly €600m.

¹⁶¹ <http://www.exist.de/DE/Home/inhalt.html> (10/2015)

¹⁶² <http://www.bmwi.de/DE/Presse/pressemitteilungen.did=674028.html> (10/2015)

¹⁶³ <http://high-tech-gruenderfonds.de/en/> (10/2015)

- ERP-Startfonds:¹⁶⁴:
ERP-Startfonds provides equity financing for small technology-intensive firms during the early stages of their development. Financing is supposed to enable these firms to invest into R&D as well as commercialisation. ERP-Startfonds has financed roughly 500 technology-intensive firms since its creation. The fund works on the principle of co-financing with a lead investor (e.g. venture capital fund). The fund matches the investment of the lead investor if the latter provides management support to the focal firm. The fund can invest up to €5m in a particular firm.
- INVEST – Zuschuss Wagniskapital¹⁶⁵:
INVEST provides incentives to private investors such as Business Angels who can receive 20% of their investment (maximum €250,000) into a young, innovative firm back from the Federal Government if they hold their initial equity investment (minimum €10,000) for three years. INVEST started in 2013 and has received 1,000 investor applications between May 2013 and December 2014 (EFI, 2015). Grants for a total of €11.7m were approved during this period corresponding to a total investment sum of €58.6m.
- IKT Innovativ¹⁶⁶:
IKT Innovativ is an entrepreneurship competition for newly founded firms with IT products or services at their core. Potential entrepreneurs compete with start-up plans which are evaluated by experts. The potential founders also receive coaching, feedback and access to professional networks. The winners receive start up grants of up to €30,000.

Research organisations also provide initiatives for science-based entrepreneurship which are typically financed by BMBF. Examples include the Life Science Incubator of the cancer research centre in Bonn or Helmholtz Enterprise. The latter can for example provide funding for up to three years for researchers from the Helmholtz society for developing business plans and commercialisation strategies¹⁶⁷. Entrepreneurship is also part but not the exclusive goal of the target portfolio of several other R&I policy programmes. These include the Leading-Edge Cluster Competition ('Spitzencluster-Wettbewerb') or the Central Innovation Programme for SMEs (ZIM).

Given that the Laender are responsible for university education, many initiatives related to encouraging science based entrepreneurship in Germany are due to their initiation. These initiatives are often times in the form of incubators, entrepreneurship advisers or consultants. Examples include (BMBF, 2014c): Humboldt-Innovation GmbH of Humboldt-University in Berlin which provides entrepreneurship consulting and services which have since 2005 resulted in more than 50 new firms; business plan competitions in the project "Spin off" of the research association of Mecklenburg-Vorpommern or the "Startercenter" of the University of Saarland which has hosted 255 newly founded firms since 1995.

Apart from the creation of new firms, support for R&I in SMEs particularly central to the German economy. SMEs are the most important source for employment and value added in Germany, more important than in any other European country and this importance has grown in recent years (European Commission, 2014a). At the same time many of these SMEs (often time referred to as 'Mittelstand') are highly specialized, innovative and active on export markets. German SMEs are substantially more likely to perform in-house R&D and engage in collaborations than the average SME in EU-28 (European Commission, 2015c). This is also reflected in innovation outputs. SMEs in Germany are almost 30% more likely than EU-28 average to introduce products and processes but also more marketing and organisational innovations (European Commission, 2015c).

¹⁶⁴ <https://www.kfw.de/inlandsfoerderung/Unternehmen/Gr%C3%BCnden-Erweitern/Finanzierungsangebote/ERP-Startfonds-%28136%29/> (10/2015)

¹⁶⁵ <http://www.bmwi.de/DE/Themen/Mittelstand/Mittelstandsfinanzierung/invest.html> (10/2015)

¹⁶⁶ <http://www.gruenderwettbewerb.de/> (10/2015)

¹⁶⁷ http://www.helmholtz.de/en/research/technologietransfer/foerderinstrumente/helmholtz_enterprise/ (10/2015)

Given the importance of SMEs for the German economy, virtually every major R&I policy initiative involving business refers to the challenges and opportunities of SMEs. This includes the High-Tech Strategy or Digital Agenda 2014-2017 (see section 2.1 of this report). Several innovation policy instruments are particularly directed at SMEs. Among the most important ones are (BMBF, 2014c):

- Central Innovation Programme for SMEs ('Zentrales Innovationsprogramm Mittelstand' ZIM)¹⁶⁸:
ZIM is an initiative of BMWi to strengthen innovativeness and competitiveness of SMEs in Germany. ZIM is not limited to a particular industry or technology field. Criteria for financial support through ZIM are the innovation content and commercialisation potential of a project. Otherwise, SMEs have a high degree of flexibility within ZIM. They can choose topics, conduct project R&I in-house or collaborate with a university or research institute. ZIM also supports the creation of innovation networks across firm boundaries. ZIM has approved 29,000 projects since its start in 2008¹⁶⁹. The Federal Government budgets €513m for ZIM in 2014 which has provided a total of €3,9b in grants since 2008. A recent ZIM monitoring report from September 2014 highlights the flexibility of ZIM grant applications as a major advantage from the perspective of firms as well as its positive effects on private R&D investment and employment¹⁷⁰.
- ERP-Innovation Programme ('ERP-Innovationsprogramm')¹⁷¹:
The programme targets the needs of SMEs to finance innovation activities which do typically not provide significant collateral for bank lending or only at high interest rates. Two combinable financing options are available: a regular loan with usually below-market interest rates and/or a subordinated credit tranche for which no collateral has to be provided. ERP-Innovation Programme is administered by government owned promotional bank KfW. The programme is designed to provide loans for applied R&D in SMEs. Repayment plans are designed to incorporate the time for commercialisation of the underlying innovation. Loans in the amount of €1.3b for 629 applications have been provided in 2014.
- KMU-innovativ:¹⁷²
KMU-innovativ is an initiative by BMBF targeting excellent innovation with high commercialisation potential of SMEs within nine technology fields; biotech, medical devices, ICT, nanotech nanotech (from 2016 extended to materials in general), production technology, technology for resource and energy efficiency, photonics, electronic systems and e-mobility as well as research for civil security. KMU-innovativ provides a special piloting service to potential applicants and a fast application process which is also attractive to small SMEs. The programme provided €100m in grants in 2012 either to SMEs directly (60%) or their research partners.
- German Federation of Industrial Research Associations ('Arbeitsgemeinschaft industrieller Forschungsvereinigungen' AiF) „Otto von Guericke“)¹⁷³:
- AiF was founded in to 1954. Its primary purpose is to bridge basic research and industrial application of innovation. AiF manages a network of 100 research associations for applied research across business sectors including research organisations and universities. It has roughly 50,000 firm members (mostly SMEs) and administers public funding mostly on behalf of BMWi (€490m in 2013).

¹⁶⁸ <http://www.zim-bmwi.de/> (10/2015)

¹⁶⁹ <http://www.zim-bmwi.de/aktuelles/staatssekretaerin-gleicke-uebergibt-20.000-zim-zuwendungsbescheid> (10/2015)

¹⁷⁰ <http://www.zim-bmwi.de/download/studien-berichte-expertisen/rkw-studie-09-2014> (10/2015)

¹⁷¹ <https://www.kfw.de/inlandsfoerderung/Unternehmen/Innovation/Finanzierungsangebote/ERP-Innovationsprogramm-%28180-185-190-195%29/> (10/2015)

¹⁷² <http://www.bmbf.de/de/20635.php> (10/2015)

¹⁷³ <http://www.aif.de/home.html> (12/2014)

Apart from these programmes there are also initiatives with a regional or topical focus such as for Innovation Competence in East Germany ('Innovationskompetenz INNO-KOM-Ost') or climate change ('Nationale Klimaschutzinitiative') (BMBF, 2014a).

5.3 Entrepreneurship skills and STEM policy

Germany has participated in the following international evaluation studies of schools, school education and competences at various age groups (BMBF, 2014c):

- PIRLS (Progress in International Reading Literacy Study) under the heading of IGLU ('Internationale Grundschul-Lese-Untersuchung') in Germany for primary schools
- TIMSS (Trends in International Mathematics and Science Study) for fourth grade students
- PISA (Programme for International Student Assessment) for 15 year old students
- ICILS (International Computer and Information Literacy Study) of school students
- PIAAC (Programme for the International Assessment of Adult Competencies) for adults
- The German school system ranks mid-field in comparative studies such as PISA with above average performance in some domains. Especially the PISA and IGLU comparative studies have triggered reforms in the German school systems. Improvements in education are facilitated by comparison and competition among the Laender because education falls under Laender responsibility. There are some indications that changes to secondary schools show success while research is still ongoing. Reading and math skills of 15 year olds or fourth grade students are improving over time (BMBF, 2014b). It is noteworthy that improvements originate especially from students with the lowest initial competences and with migration backgrounds. The computer and information literacy competences are about EU average and only slightly above OECD average. This reveals the recent International Computer and Information Literacy Study of the International Association for the Evaluation of Educational Achievement (IEA) among 8th grade students (Bos et al., 2014). The study finds that a particular shortcoming in Germany does not stem from the availability of digital equipment in schools but its usage in education. Independently, BMBF has announced to provide funding of €500m over the next ten years for quality improvements in teacher training ('Qualitätsoffensive Lehrerbildung') in cooperation with the Laender¹⁷⁴.

The education system has improved its performance by increasing the number of secondary education graduates qualifying for university education ('Allgemeine Hochschulreife'). 42.3% of students in the relevant age group were qualified in 2012 compared with 29.6% in 2006 (BMBF, 2014b). The total number of students enrolled in German universities reached a record high in the winter semester of 2015/2016 with almost 2.8m¹⁷⁵. New enrolments have been 1.9% lower compared with previous years. This reflects two exceptions in the German education system in recent past. First, with the abolishment of the mandatory military service more students have entered universities. Second, the length of secondary education for obtaining the qualification to enrol at a university was shortened by one year. Hence, two generations of secondary school graduates entered universities at the same time. Not all Laender have agreed and implemented this change at the same time and the effect on student numbers has therefore been prolonged. However, the exceptional effects are about to expire. A side effect of these changes is that the average student reaching the end of secondary education is now younger (19.4 years) (BMBF, 2014b). The German Centre for Research on Higher Education and Science Studies ('Deutsches Zentrum fuer Hochschul- und Wissenschaftsforschung,' DZHW) finds the percentage of university students quitting their studies was 28% in 2012 which is largely unchanged from previous years (DZHW,

¹⁷⁴ <https://www.bmbf.de/de/qualitaetsoffensive-lehrerbildung-525.html> (10/2015)

¹⁷⁵ https://www.destatis.de/DE/PresseService/Presse/Pressemitteilungen/2015/11/PD15_432_213.html (1/2016)

2014). Rates in mathematics, information sciences, natural sciences, and technology (MINT) are higher. 39% of university students in maths and natural sciences do not finish their studies, 36% in engineering. The latter has been reduced significantly compared with previous student generations. Nevertheless, dropout rates in MINT study programmes are still seen as an important issue affecting the availability of a pool of qualified scientists in Germany in the future (Stifterverband, 2015b).

To address the issue of drop-out rates further, the extension of the Higher Education Pact ('Hochschulpakt') for universities until 2020 includes for the first time dedicated funds for quality improvements increasing graduation rates (10% of total funds)¹⁷⁶.

Focusing on vocational training, the German training system of apprenticeships ('Berufsausbildung') is long established and provides dual part time training in vocational schools and part time work at firms. 497,427 students entered the dual system in 2013 which equals 51.4% of students entering vocational training (BMBF, 2014b). The level and share of students has been rather stable over time. The dual system is accompanied by fulltime vocational schools (21.9%) and transitory support systems (26.6%) for students to find jobs. There are significant concerns in Germany that the current system of dual training will not provide enough skilled employees for the future ('Fachkraeftmangel'). The German R&I system has traditionally benefitted from a labour force in which innovation is not exclusively the task of university trained scientists and engineers. Instead, a broad group of employees with human capital acquired through apprenticeships, on the job training and professional experience ('Facharbeiter') has complemented scientific research and discovery in crucial ways. However, in recent years preferences of school students have shifted towards academic skill development in universities. Among professions for which apprenticeship supply does not meet demand are several with relevance for R&I in Germany as evidenced by the supply to demand ratios: Technicians (-10%), electrical technician (-10%) and IT (-11%) (BMBF, 2014b).

Germany has comparatively high replacement needs of skilled employees. 16.4% of engineers, mathematicians and natural scientists are 55 years and older compared with 11.2% in France and 13.3% in the UK (Baethge et al., 2015). Among the employees with engineering-technical tasks the share is even higher (19.2%, France: 13.2%, UK: 14.8%). The needs from aging employees are less pronounced in ICT professionals and technicians.

The age structure of current employees and the decreasing attractiveness of vocational training careers pose challenge to the German human resource base. Policy initiatives to address these challenges include improvements of recognition of professional skills and diploma from abroad. In 2012 the law for simplifying such recognition procedures ('Gesetz über die Feststellung der Gleichwertigkeit von Berufsqualifikationen, Berufsqualifikationsfeststellungsgesetz - BQFG')¹⁷⁷ was enacted. 13,344 recognition applications were processed in 2013 with a positive recognition rate of almost 75% (BMBF, 2015a).

Besides, several initiatives are in place to make vocational training more attractive. These include linkages with university education as well as a simplified transition to higher education for professionals with vocational training.¹⁷⁸ The Bundestag has passed legislation on a reform of the law for the "Promotion of Advancement through Training" ('Aufstiegsfortbildungsförderungsgesetz,' AFBG) in March 2016 and the law will be enacted in August 2016. Part of the reformed law is an increase in the subsistence support for professional vocational training and advance training ('Aufstiegs-BAföG'). This will result in an increase in available budgets from Federal and Laender governments of €88m annually beginning in 2017, less in 2016 due to enactment of the reformed law

¹⁷⁶ <http://www.gwk-bonn.de/fileadmin/Papers/PFI-III-2016-2020.pdf> (9/2015)

¹⁷⁷ <http://www.gesetze-im-internet.de/bundesrecht/bqfg/gesamt.pdf> (10/2015)

¹⁷⁸ <http://www.jobstarter.de/de/ausbildung-gestalten-36.php> (10/2015)

by the middle of the year¹⁷⁹. Besides, the Standing Conference of the Ministers of Education and Cultural Affairs of the Laender ('Kultusministerkonferenz,' KMK) has agreed in 2009 to provide this opportunity for individuals with certain degrees of vocational trainings, e.g. master craftsmen ('Handwerksmeister')¹⁸⁰. The implementation of this agreement is due to the Laender and they have found varying solutions and requirements.¹⁸¹ The acceptance of this opportunity for university education is growing slowly. In 2012 2.6% of new university students used the opportunity (BMBF, 2014b). Often times these students choose universities for applied sciences or distance study universities. SMEs receive support for recruiting through Chambers of Commerce ('Handwerks-, Industrie- und Handelskammern') based on a dedicated programme ('Unterstützung von kleinen und mittleren Unternehmen bei der passgenauen Besetzung von Ausbildungsplätzen sowie bei der Integration von ausländischen Fachkräften') which received funding by the Federal Government and the European Social Fund of €10.1m in 2015 (BMBF, 2015b).

Technical colleges ('Fachhochschule') and universities of applied sciences ('Berufakademie') provide opportunities to connect university education with direct application in business. They allow students to enrol themselves into higher education with a more clearly defined focus on application skills. 37.4% of students opted for starting their studies at a technical college in the winter semester of 2012 (BMBF, 2014b). Individual Laender have started initiatives to increase the role of universities of applied sciences to connect higher education with business needs. Particularly Baden-Wuerttemberg is investing into promoting research at technical colleges.

Lifelong learning is an important element of the German education system. Roughly a third of all employees has participated in company funded training in 2012 and also small firms participate frequently (Baethge et al., 2015). Support schemes, such as scholarships or tax deductions, are largely directed at employees, not necessarily firms¹⁸².

There is currently little information on the availability of entrepreneurship education in Germany. However, the share of students entering college for becoming teachers of MINT topics is at 25.6% of all students starting their studies for teaching degrees in 2013 and this number is decreasing (2012: 26.8%) (Stifterverband, 2015b). In a positive development, BMBF has initiated a Pact for Teaching Quality ('Qualitätspakt Lehre') in higher education¹⁸³. The Federal Government provides €2b in funds between 2011 and 2020 for universities to develop new teaching programmes. These can range from organizing small groups bachelor programmes for students with an early interest in science or study programmes with a more immediate link to practical problem solving.

5.4 Access to finance

Young and especially knowledge-intensive companies struggle with securing external financing. Large parts of R&D investments are required for the wages of engineers and scientists as well as for highly specialized equipment, e.g. labs. Hence, such investments generate very little collateral for traditional bank financing. Young and high-tech firms are therefore often times limited to their own cash flows and equity financing to fund R&D. The availability of venture capital investors is therefore critical. Such investors have expertise in selecting and monitoring particularly promising firms. They can also advise the often times inexperienced management of young firms professionally, e.g. on commercialisation and staffing strategies, or provide access to professional networks.

¹⁷⁹ <http://www.bundesregierung.de/Content/DE/Artikel/2015/10/2015-10-14-dritte-novelle-meister-bafoeg.html> (10/2015)

¹⁸⁰ http://www.kmk.org/fileadmin/veroeffentlichungen_beschluesse/2009/2009_03_06-Hochschulzugang-erful-qualifizierte-Bewerber.pdf (10/2015)

¹⁸¹ For an overview see: http://www.kmk.org/fileadmin/veroeffentlichungen_beschluesse/2014/2014_08_00-Synopse-Hochschulzugang-berufl_Qualifizierter.pdf (10/2015)

¹⁸² https://www.bmbf.de/pub/Ausbildung_Job_und_dann.pdf (10/2015)

¹⁸³ <https://www.bmbf.de/de/qualitaetspakt-lehre-524.html> (10/2015)

The majority of entrepreneurs in Germany does not experience difficulties in financing. 20% of entrepreneurs report such difficulties 2014. This is a historically high value which has only been reached once before in 2012 (KfW, 2015). Then again, start-ups are heterogeneous. They experience more difficulties in securing financing when the new firm is their full-time activity (27%), it requires capital investment (23%) and external financing (38%) (KfW, 2015). There are no precise numbers available for how financing needs and supply change throughout the lifecycle of a firm. However, the Community Innovation Survey for Germany provides some information on the link between financing and innovation projects in firms. 35.6% of firms in Germany report that a lack of financing was not a relevant barrier to their innovation projects in 2012, 9.5% report that it was a highly important obstacle (10.6% of firms with fewer than 50 employees) (ZEW, 2014). For comparison, 18.2% of firms mention a lack of qualified personnel as a highly important barrier for innovation, 62% strong price competition.

Within the European Union Innovation Scoreboard of 2015 Germany is generally classified as an innovation leader but its venture capital market is significantly smaller than the average of EU-28 and of other innovation leaders. What is more, the share of its venture capital market as a percentage of GDP is declining (European Commission, 2015c): In 2013 the venture capital market in Germany was 0.04% of GDP, compared with 0.05% in 2012 and 0.06% as the average of all EU-28 countries. Other innovation leader EU member states, such as Denmark (0.1%), Finland (0.08%) and Sweden (0.08%) have significantly larger venture capital markets.

The European Private Equity & Venture Capital Association (EVCA) compiles an annual yearbook which provides insights into the structure of venture capital funding (EVCA, 2015). In 2014 751 companies have received a total of €663.8m. These numbers are largely in line with 2013 in which 740 companies received €716.4m. The largest recipients of venture capital in Germany in 2014 operate in communications (26.9%), life sciences (24.4%) as well as computer and consumer electronics sectors (18.4%). These top 3 recipient sectors of venture capital are largely identical to the previous year and for Europe as a whole.

In terms of policy initiatives to foster the venture capital market in Germany, both active approaches in which government acts as a venture capital investor and passive approaches in which the government incentivizes private investors are present. Many of the policies target entrepreneurship in high-tech sectors and therefore overlap with science-based entrepreneurship. Among the most important policy initiatives are (BMBF, 2014c):

- High-tech Start-Up Fund ('High-Tech Gründerfonds', HTGF): HTGF is an investment fund for technology start-ups of BMWi, government owned development bank KfW as well as industrial partners. Its initial investment endowment in 2005 was €272m. Investments are limited to €500,000 and the fund provides access to coaches as well as venture capital investors for future investment rounds. The HTGF portfolio encompasses 330 investments (March 2014).
- ERP-Startfonds: ERP-Startfonds provides early stage equity financing for R&D intensive firms. The fund can invest up to €5m in a particular firm and always acts as a co-investor, i.e. firms have to have a private lead investor whose investment is matched by ERP-Startfonds. ERP-Startfonds has financed roughly 500 technology-intensive firms since its creation.
- INVEST – Zuschuss Wagniskapital: INVEST provides incentives to private investors such as Business Angels who can receive 20% of their investment (maximum €250,000) into a young, innovative firm back from the Federal Government if they hold their initial equity investment (minimum €10,000) for three years. INVEST started in 2013 and has received 1,000 investor applications between May 2013 and December 2014 (EFI, 2015). Grants for a total of €11.7m were approved during this period corresponding to a

total investment sum of €58.6m. While these numbers signal a general interest in the programme they correspond only to a quarter of the funds which were initially appropriated for the first two years (EFI, 2015). Part of the explanation for this discrepancy was a lack of clarity about how the grant would be taxed. The Federal Government has therefore set the legislative process in motion to tax exempt the grant (EFI, 2015).

Additionally, BMWi has created the so called "Mikromezzaninfonds" in 2013 as a fund for providing equity financing for start-ups and young firms for up to €50,000¹⁸⁴. The fund has approved 1,400 investments with a volume of €59m between September 2013 and June 2015¹⁸⁵. BMWi has increased available funds by €13m for 2015.

The Expert Commission for Research and Innovation (EFI) raises several issues related to the comparatively small size of the venture capital market in Germany which are more related to taxation and institutional frameworks (EFI, 2015):

- Germany has currently rather restrictive rules for how carried forward deficits ('Verlustvortrag') are treated in taxation. Within the current system, carried forward deficits are forfeited when an investor acquires shares of a company. Particularly R&D-intensive start-up firms are likely to incur substantial losses during the initial stages of their existence at which they have to make significant investments for multiple years before revenues from the resulting products or services emerge. The attractiveness of investments in such firms diminishes if a new investor triggers the eradication of tax reductions based on carried forward deficits. A law that was intended to reform this system ('Gesetz zur Modernisierung der Rahmenbedingungen für Kapitalbeteiligungen – MoRaKG') is currently stalled because of pending litigation about its compliance with EU state aid laws.
- EFI (2015) also warns of unintended consequences for venture capital investments from discussed but not enacted changes in taxation laws such as a broader inclusion of taxable profits originating from sales of companies ('Veräußerungsgewinne bei Streubesitzanteilen an Kapitalgesellschaften') or carried interests. The report also highlights that, in contrast to other countries, administrative services of fund managers are subject to value added taxation. Establishing and managing a fund in Germany is therefore comparatively more costly.
- The German pension system is largely based on immediate transfers from current workers to retirees. Hence, Germany lacks large institutional investors, such as pension funds, which can serve as large scale "anchor" investors of firms providing valuable quality signals about investment quality to other investors. EFI (2015) cautions therefore that regulations limiting the range of potential investments of remaining institutional investors, such as insurance companies, should not be further restricted. It welcomes the announcement of a new venture capital fund created by the Federal Government with the European Investment Fund (EIF) with a volume of €500m.
- Finally, EFI (2015) identifies a lack of exit options for venture capital investors on liquid capital markets for young firms as a barrier to increased investments. It suggests a pan-European stock exchange segment for providing these exit options and overcoming liquidity constraints on fragmented, national capital markets.

Specific public support in relation for Business Angels in Germany includes a combination of some – albeit limited – tax relief for capital gains, the support for the development of networks – including the national association of BANs and the creation of the above mentioned public-private funds co-investing in high-tech start-ups.

¹⁸⁴ <http://www.mikromezzaninfonds-deutschland.de/> (9/2015)

¹⁸⁵ <http://www.bmw.de/DE/Themen/mittelstand.did=728072.html> (9/2015)

In relation to the promotion of networks, the national BANS association – BAND – was created with the support of the Federal Government and private sponsors. It operates as a network of networks and organises the Business Angels Day, a national network for experience exchange and the Angel of the Year award. Other activities include the sponsoring of the Business Angel panel presented earlier and the promotion of investment readiness activities. In addition, as a national association, it represents and promotes the interests of Business Angels. A number of support schemes for Business Angels are also available at regional level.

5.5 R&D related FDI

The World Investment Report provides an overview on flows of foreign direct investment (FDI) (UNCTAD, 2015). Germany received FDI of US\$20.3b in 2012, US\$18.1b in 2013 and US\$1.8b in 2014. In terms of FDI outflows, FDI from amounted to US\$66.1b in 2012, US\$30.1b in 2013 and US\$122.2b in 2014. Between 2009 and 2014 FDI outflows of Germany have always surpassed FDI inflows. FDI in Germany is more likely to be greenfield investment in nature. The value of announced greenfield FDI in Germany in 2014 is US\$53b compared with US\$7.8b greenfield FDI of German investors abroad.

FDI is not necessarily R&D-related. There are no detailed statistics on R&D intensive FDI. 4.3% of R&D expenditures in Germany were financed from abroad in 2012, which is below EU-28 average (9.8%) but a significant increase compared with 2.3% in 2003 (Schasse and Leidmann, 2015). The share of R&D expenditures from abroad is particularly high in the manufacturing of basic metals in Germany (2011: 20.6%), manufacture of glass and mineral products (2011: 12.6%) as well as mining (2011: 10%). In its 2014 report the Expert Commission for Research and Innovation (EFI) devotes attention to the issue of the internationalisation of R&D and possible consequences for Germany. It concludes that it is not obvious that the R&D investments of German firms abroad put R&I at a disadvantage since significant parts of the investments are motivated by accessing new market and knowledge pools (EFI, 2014). Besides, Germany still runs a positive balance when comparing R&D investment of German firms abroad (2011: €14.8b) with R&D investments of foreign firms in Germany (2011: €16.2) (EFI, 2014).

Germany operates an online portal for information on FDI in Germany (“Invest in Germany”)¹⁸⁶. The website provides information on business opportunities, incentives for investments as well as R&D incentives but those are not particular or exclusive for foreign investors.

5.6 Knowledge markets

Markets for knowledge (also referred to as markets for technology or ideas) have important potentials for the efficiency of knowledge creation and exploitation in a country. They enable an efficient division of labour. Entrepreneurial firms with novel technologies, materials or processes often times lack the complementary assets to exploit them, e.g. manufacturing capacities, sales networks, brands. It would be a costly and lengthy process for them to find financing for the development of complementary assets. In the presence of an efficient market for technology, such firms can sell their technology, often times through licensing, to incumbent firms which already possess the complementary assets. Conversely, established firms with significant capacities for manufacturing, sales or servicing are likely better off by acquiring new knowledge or technologies on markets instead of going through the uncertain process of developing new technologies themselves. As a result the presence of efficient markets for technology benefits both entrepreneurial and incumbent firms.

¹⁸⁶ <http://www.gtai.de/> (10/2015)

The efficiency of markets for technology depends crucially on whether the market is thick (with sufficient buyers and suppliers), safe and uncongested (Gans and Stern, 2010). These factors are interconnected and relate to the underlying intellectual property rights regime (IPR). The institutional environment in Germany ranks high with regard to IPR protection based on the coverage of IPR protection and its enforceability (Park, 2008). A more recent survey among business executives of the World Economic Forum ranks IPR protection in Germany 21st out of 144 economies as part of the Global Competitiveness Report 2014-2015¹⁸⁷. IPR protection is fairly skewed in this indicator, i.e. Germany achieves a rating of 5.4 (out of a maximum of 7) which puts it not far from the leading economy Finland (6.2) and very close to Sweden (5.5), Denmark (5.3) and the US (5.4).

German inventors are very active in applying for patents which enables them to engage in licensing agreements. The EU Innovation Scoreboard of 2015 shows that they apply for 6.89 patents as part of the Patent Cooperation Treaty (PCT) per billion GDP (European Commission, 2015c). EU-28 averages are 3.78 patent applications. Germany is also significantly above EU-28 averages in the usage of community trademarks and community design protection. These protection instruments do not protect a particular technology but can allow a firm to develop a unique brand based on words, slogans or designs which cannot be copied by competitors. Germany had 7.49 community trademarks per billion GDP in 2013 (EU-28: 5.83) and 1.32 protected community designs (EU-28: 1.13) (European Commission, 2015c).

Focusing on the demand side for external knowledge, 12.1% of all firms in Germany (CIS industry selection) have acquired external knowledge (e.g. through licensing) and spent a total of €2.14b in 2012 (ZEW, 2014). The size of expenditures is significantly smaller than for external R&D which is largely not traded on markets because it requires a contractual agreement between partners (2012: €12.3b). Both numbers are significantly smaller compared with what firms invest into machinery and equipment for their innovation activities (2012: €37.8b). Machinery and equipment can embody novel knowledge in itself and its functions.

Compared with 2008 both the share of firms acquiring external knowledge in Germany (2008: 18%) and their expenditures (2008: €3.4b) have decreased significantly (ZEW, 2014). A possible explanation can be the increase in innovation collaborations (see section 5.7 of this report). License and patent revenues from abroad (0.78% of GDP) have increased strongly (+19%) and are above EU average (0.65% of GDP) in 2014 (European Commission, 2015c).

Major policy initiatives in Germany have been directed at increasing supply and demand on markets for technology. On the supply side the programme "Protection of Ideas for Commercial Use" ('Schutz von Ideen für die Gewerbliche Nutzung SIGNO) of BMWi targets universities, companies and inventors since 2008¹⁸⁸. The goals of the program are to provide information and promote strategic thinking about commercial use of inventions. The monitoring report of SIGNO from June 2014 shows that SIGNO has led to 542 patent applications, 530 patent sales and 375 licensing agreements among other outcomes since 2008¹⁸⁹. The report concludes that the programme has performed well in creating awareness and momentum for commercialisation strategies but requires adaptations to the needs of various stakeholder groups (Kulicke, 2014).

On the demand side, Technology Alliance ('TechnologieAllianz') of BMWi provides an online platform for the commercialisation of knowledge from universities and research organisations¹⁹⁰. TechnologieAllianz bundles technologies on offer in one online location, secures IPR rights and offers assistance from trained consultants with

¹⁸⁷ <http://reports.weforum.org/global-competitiveness-report-2014-2015/economies/#economy=DEU> (12/2014)

¹⁸⁸ <http://www.signo-deutschland.de/> (12/2014)

¹⁸⁹ http://www.signo-deutschland.de/e5072/e13035/SIGNO_Erfolgskontrolle_Endbericht_FraunhoferISI.pdf (10/2015)

¹⁹⁰ <http://www.technologieallianz.de/angebote.php> (10/2015)

industry/technology expertise. TechnologieAllianz also offers technologies from external partners for which it provides quality assurance. TechnologieAllianz has currently 28 members. Among those are individual universities, research organisations (e.g. Fraunhofer patenting and licensing) as well as patent organisations for Laender universities (e.g. for 28 universities in Bavaria "Bayerische Patentallianz"). TechnologieAllianz is member of the international Alliance of Technology Transfer Professionals (ATTP)¹⁹¹. Otherwise there is little information available about the coordination of market platforms for technology internationally.

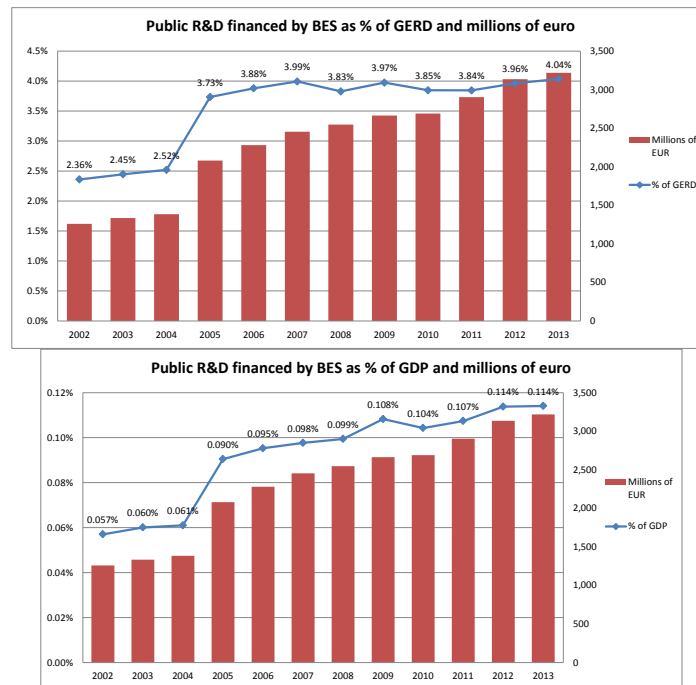
¹⁹¹ http://www.technologieallianz.de/aktuelles_pressemitteilungen.php?id=692 (10/2015)

5.7 Knowledge transfer and open innovation

5.7.1 Knowledge Transfer Indicators

Funding: BES-funded/publicly-performed R&D

Figure 14: BES-funded public R&D in GERMANY as % of GERD (in €MLN) and % of GDP



The level of Business Enterprise Sector (BES)-funded public R&D expenditure in Germany as a share of GERD has been relatively high and stable levels over the past years, fluctuating between 3.8% and 4% between 2005 and 2013. Fluctuations changed into a slight upward trend for years 2012 and 2013. The picture is similar when considering BES-funded public R&D expressed as a share of GDP. In absolute terms, public R&D funded by BES has constantly been increasing, including during the economic crisis.

The below figure 15 shows the income raised by the four major non-university PROs (Fraunhofer-Gesellschaft (FhG), Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren (HGF), Leibniz-Gemeinschaft (WGL), Max-Planck-Gesellschaft (MPG)) through R&D projects with private business sector and through contract research but without licencing income. One notices that the private sector as source of income is most important for FhG which is not surprising as FhG is more oriented towards applied research than the other three RPOs. Moreover, the figure also clearly shows the growing importance of external funding from private sector for FhG which is not the case for WGL and MPG and applies only to a lesser extent to HGF.

Figure 15: External funding from private sector - income obtained for R&D from private sector, without licensing income¹⁹²

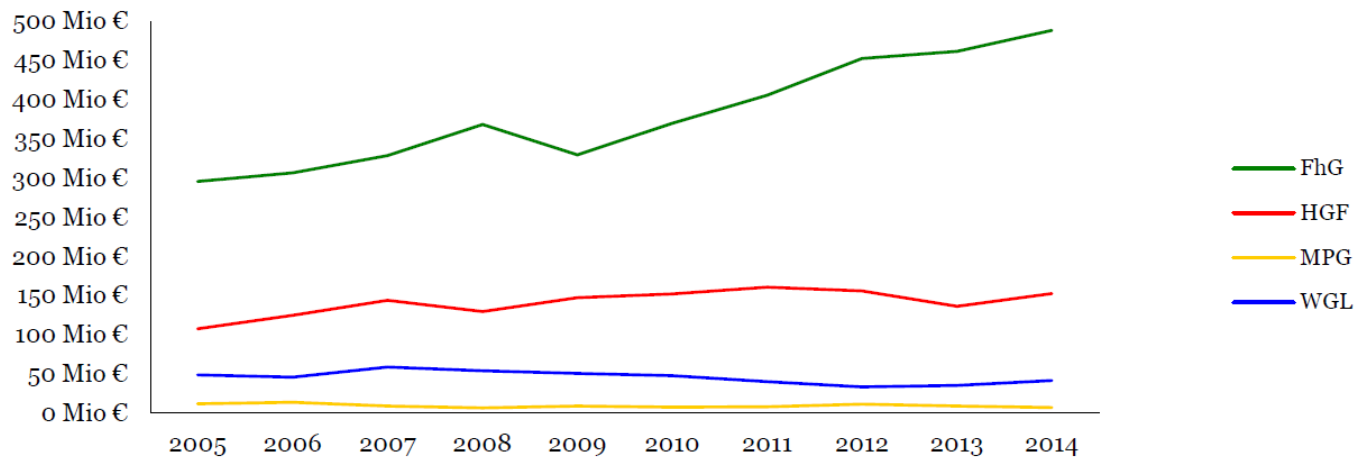
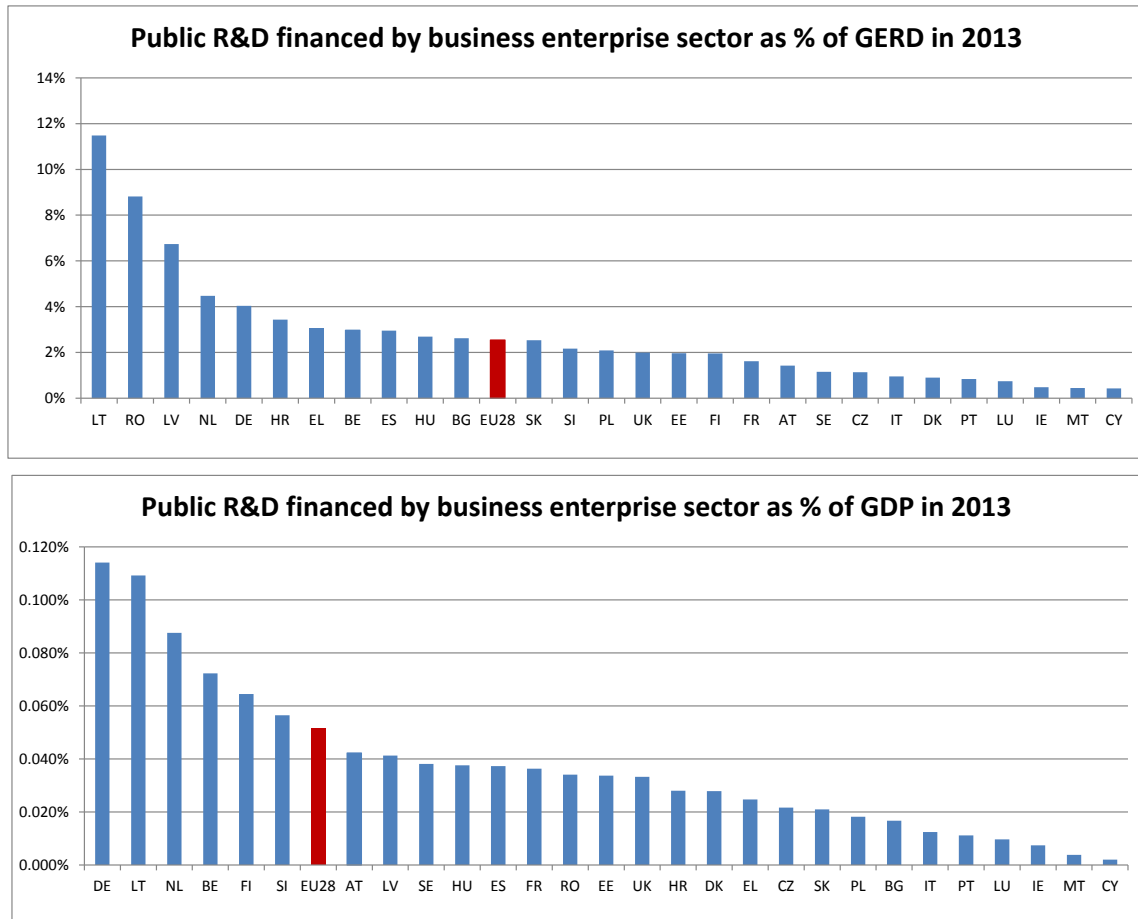


Figure 16: BES-funded public R&D as % of GERD and as % of GDP in 2013 in Member States¹⁹³



The two charts in Figure 16 show the values of BES-funded public R&D in all EU-28 as percentages of GERD and GDP respectively. Germany's levels are well above the EU-28 average for both indicators. In terms of Public R&D funded by BES as share of GDP,

¹⁹² GWK, 2015

¹⁹³ 2013 was chosen as the latest data series providing a full comparison within EU-28.

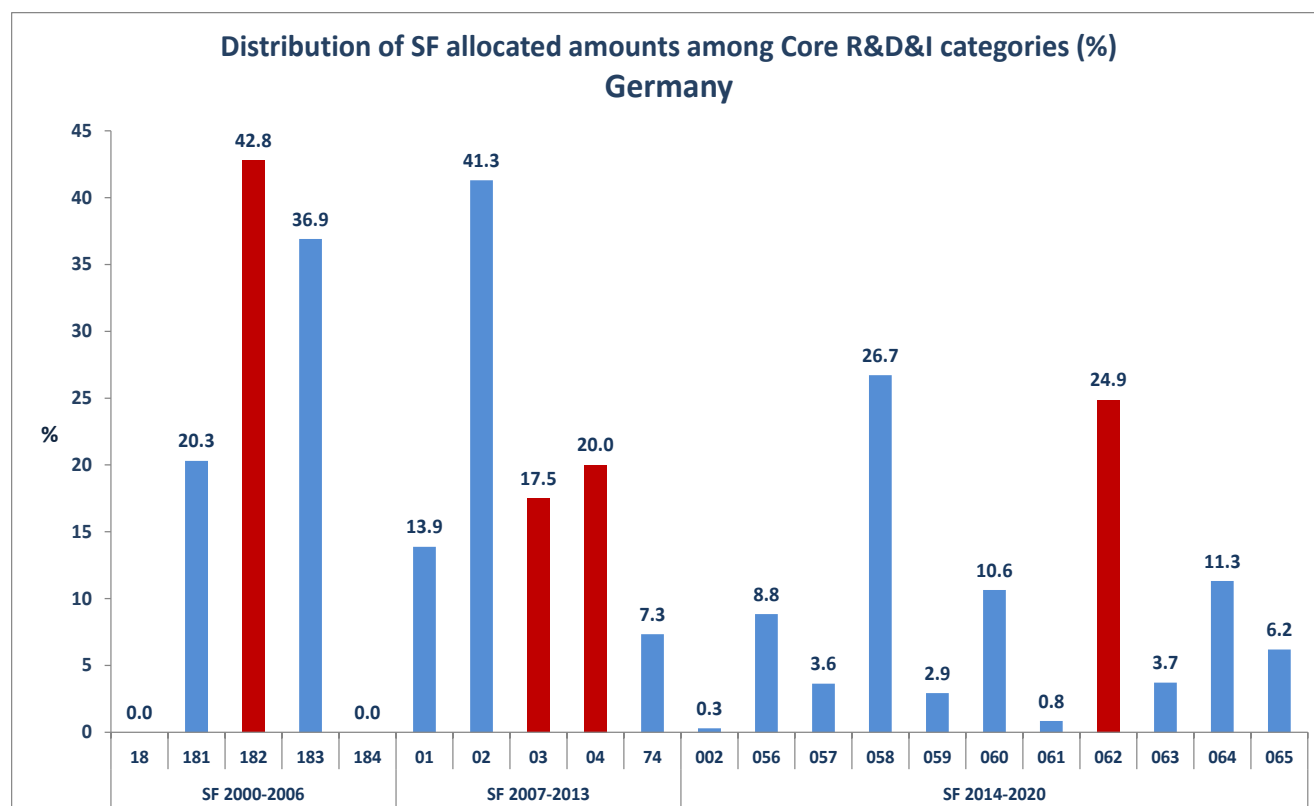
Germany tops the list of EU-28 countries with about double as much public R&D funded by BES than in the average of EU-28 countries.

Germany's innovation system is leveraged by strong links between industry and science which explains the generally high level of privately funded public R&D. There are continued efforts by federal, regional and local authorities to further improve the forging of academia-industry bonds.

Most recent data by Germany's Stifterverband also show that expenditures by German businesses for "extra-muros" performed R&D have strongly been increasing in 2013, in particular in chemical and pharmaceutical industries (+19% and +17% respectively) while intramural expenditures have been slightly declining. R&D expenditures of independent scientific and technological service providers has increased by 13.3% between 2012 and 2013, employment in this sector increased by 16.1%. A major part of the additional extramural expenditure is still spent in the private sector and not in the public sector (often in small specialised SMEs), but it can nevertheless be seen as an indication for more open corporate innovation strategies characterised by increased usage of external knowledge and competence (Stifterverband, 2015d).

Funding: Structural funds devoted to knowledge transfer

Figure 17: Structural Funds for core R&D activities 2000-2006, 2007-2013 and 2014-2020¹⁹⁴. The categories: 182 (2000-2006), 03 and 04 (2007-2013) and 062 (2014-2020) are used as proxies for KT activities.



Between 2007 – 2013 Germany allocated 37.5% of its structural funds for core R&D activities to knowledge transfer activities (compared to 42.8% in the previous programming period). This share was higher than the EU average of 30% for the 2007-2013 period and higher than the EU average of 26% in the 2000-2006 period. For the

¹⁹⁴ Figure 17 provides the Structural Funds allocated to Germany for each of the above R&D categories. The red bars show the categories used as proxies for KT. Please note that the figures refer to EU funds and they do not include the part co-funded by the Member State. The categories for 2000-2006 include: 18. Research, technological development and innovation (RTDI); 181. Research projects based in universities and research institutes; 182. Innovation and technology transfers, establishment of networks and partnerships between business and/or research institutes; 183. RTDI infrastructures; 184. Training for researchers. The categories for 2007-2013 include: 01. R&TD activities in research centres; 02. R&TD infrastructure and centres of competence in specific technology; 03. Technology transfer and improvement of cooperation networks; 04. Assistance to R&TD particular in SMEs; 74. Developing human potential in the field of research and innovation. The categories for 2014-2020 include: 002. Research and Innovation processes in large enterprises; 056. Investment in infrastructure, capacities and equipment in SMEs directly linked to Research and Innovation activities; 057. Investment in infrastructure, capacities and equipment in large companies directly linked to Research and Innovation activities; 058. Research and Innovation infrastructure (public); 059. Research and Innovation infrastructure (private, including science parks); 060. Research and Innovation activities in public research centres and centres of competence including networking; 061. Research and Innovation activities in private research centres including networking; 062. Technology transfer and university-enterprise cooperation primarily benefiting SMEs; 063. Cluster support and business networks primarily benefiting SMEs; 064. Research and Innovation processes in SMEs (including voucher schemes, process, design, service and social innovation); 065. Research and Innovation infrastructure, processes, technology transfer and cooperation of enterprises focusing on the low carbon economy and on resilience to climate change. This allocation is not very precise, since the category 'Research and Innovation in SMEs' also comprises SMEs including voucher schemes, which may be used for contract research, whereas the funds allocated to infrastructure are the highest. The latest Innovation Union Scoreboard 2015 ranks the Slovak Republic as moderate innovator..

current programming period, 24.9% of Core R&D funds are budgeted for knowledge transfer activities.

Cooperation: Share of innovative companies cooperating with academia

Figure 18: CIS survey 2012 – share of enterprises cooperating with academia

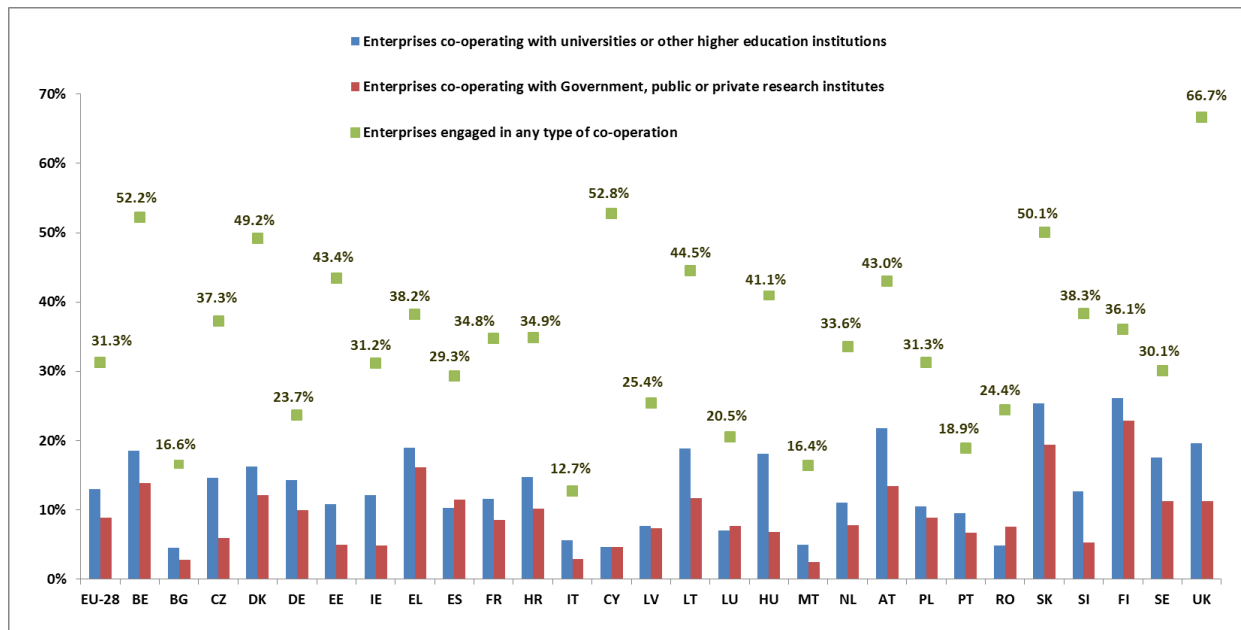


Figure 18 depicts the level of cooperation activities of innovative companies in the EU-28, according to the CIS 2012. According to CIS survey 2012, 23.7% of German innovative companies are engaged in some type of cooperation which is less than the EU average of 31%. However, this figure constitutes an increase compared to the period 2006-2008 of almost 5% (CIS2008). The share of innovative companies cooperating with universities and higher education institutions is 14.3% which is slightly above the EU average of 13% and is up from 11% in CIS2008. It is also higher than in e.g. France but significantly lower than in other countries classified as innovation leaders in the innovation Union Scoreboard, such as Finland (26.1%) and Sweden (17.6%). Almost 10% (9.9%) of German innovative companies are engaged in cooperation with government and public or private research institutes. Again, this is higher than the EU average (8.9%) and the corresponding figures for France (8.5%) or Italy (2.9%). Other innovation leaders, however, have comparatively more innovative businesses cooperating with the public sector and private research institutes (Finland 22.9% and Sweden 11.3%) (Sofka, 2015).

German universities, too, show an increased interest in collaborations with private firms. In a recent survey of the business association Stifterverband among the leadership of universities in Germany (Stifterverband, 2014) 93% of universities would like to increase their collaborations with firms. Universities see such collaborations mostly as opportunities to increase their financing. Among the challenges for more university-business collaborations the report finds differences in time and risk perspectives (85% of respondents), project cost coverage (82%) and costs for finding fitting partners (74%) as the most important ones.

Cooperation: Technology Transfer Offices (TTOs), incubators and technological parks

There are 153 innovation and business incubator centres associated to the German Association of Innovation, Technology and Business Incubation Centres (ADT). These centres unite more than 5.800 companies and over 46.000 employees. The centres have

so far successfully outsourced more than 17.400 companies¹⁹⁵. It should be noted that the actual number of technology parks and incubation centres in Germany is estimated to be higher.

Most of Germany's 395 universities and universities of applied sciences now have their own knowledge transfer or technology transfer offices of various sizes. At national level, the TechnologieAllianz unites patent marketing agencies and technology transfer agencies in a single network (for more information see chapter 5.6).

Cooperation: Share of public-private co-publications

Figure 19: Co-publications by field 2003–2013 in Germany. Scopus database

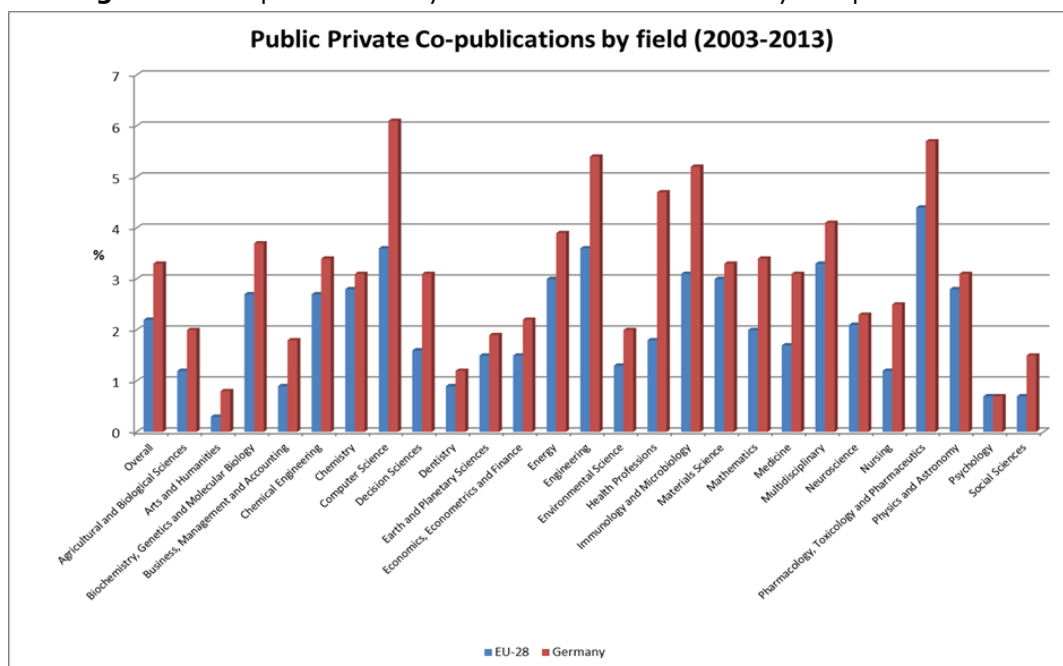


Figure 19 shows the 2003-2013 average percentage of academia-industry co-publications by field in Germany compared to the European average. It provides an overview of the share of publications with authors from both academia and business. Germany exceeds the EU-28 average in almost all fields between 2003 and 2013. German shares are especially high in computer sciences, engineering and pharmaceuticals. Moreover, in 2013 Germany had 57.8 public-private co-publications per million of population compared to 29 for the EU-28 (and 52.5 for FR and 67.5 for UK)¹⁹⁶.

Cooperation: Inter-sectoral mobility

Another mode for the exchange of knowledge are industrial PhD programmes. PhD students in Germany are not necessarily employed by universities. 25% of all PhD students in Germany were employed by non-university research institutes or companies in the winter semester of 2010/11 (BMBF, 2013a). Such external PhD projects ('externe Promotion') emerge typically on a case by case basis in which potential PhD students contact university supervisors. Many companies support the PhD projects of employees, e.g. through reduced work hours, but there is no standard model of industrial PhD projects in place. Apart from industrial PhD projects, programmes exist to expand current skill sets among employees which go beyond existing industry profiles while not explicitly encouraging intersectoral mobility. Such programmes promote for example competences for green and sustainable development across industries ('Berufsbildung

¹⁹⁵ German Association of Innovation, Technology and Business Incubation Centres (ADT), http://www.adt-online.de/index.php?article_id=4

¹⁹⁶ RIO elaboration based on Scopus data.

für nachhaltige Entwicklung befördern. Über grüne Schlüsselkompetenzen zu klima- und ressourcenschonendem Handeln im Beruf') or offer re-training for employees switching into sectors with particularly strong demand such as elderly care ('Ausbildungs- und Qualifizierungsoffensive Altenpflege') (BMBF, 2015b).

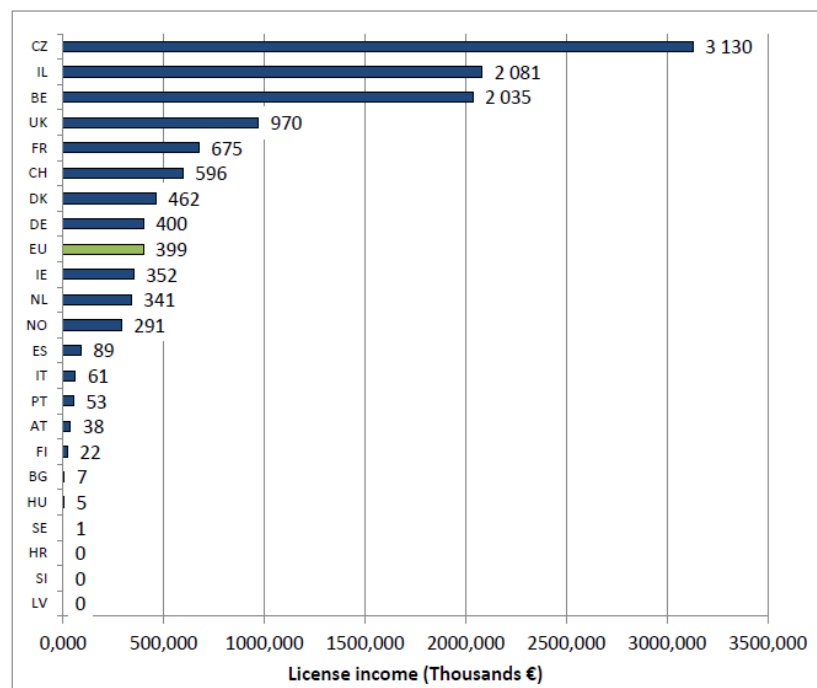
Cooperation: Patenting activity of public research organisations and universities together with licensing income

The Knowledge Transfer Study allows benchmarking the German performances with the other surveyed countries as well as with the EU average.

According to the European Knowledge Transfer Indicator Survey 2011 and 2012, 2.6 patents were granted per 1.000 research staff over the years 2011 and 2012 combined in Germany, which is clearly below the EU average of 4.5 patents granted and also below the numbers for most other EU countries. Interestingly, Sweden (2.9), Denmark (2.1) and Finland (1.3) also score low on this indicator. Over the same period, 5 new licence agreements were concluded per 1 000 research staff which is also somewhat below the EU average of 6.5 agreements per 1 000 research staff. However, the licence income received in 2011 and 2012 combined was slightly higher than EU average with €400 000 per 1.000 research staff (Figure 20). Over the same period, 60.4 research agreements were concluded per 1 000 researchers in Germany. This is again clearly below the EU average number of 82.8¹⁹⁷.

Figure 20: License income per 1 000 research staff by country. EKTIS 2011-2012 survey

Exhibit 3-35: Thousands Euros of license income per 1,000 research staff by country, EKTIS 2011 and 2012 results combined



Source: MERIT, European Knowledge Transfer Indicator Survey 2011 and 2012.

For the four big German public research organisations Fraunhofer Society, Helmholtz Association Leibniz Association and Max-Planck-Society a more detailed analysis shows that in 2014 the four organisations together held 13.814 patent families out of which 1.198 (new) patent applications had been filed the same year. In 2014, the organisations also had 5.736 standing licence agreements out of which 530 had been concluded that same year. Income from these licensing agreements added up to

¹⁹⁷ MERIT, European Knowledge Transfer Indicator Survey 2011 and 2012:

€173.5m for all four organisations together in 2014. Fraunhofer alone accounts for approx.. 75% of the income raised (GWK, 2015).

Cooperation: Companies

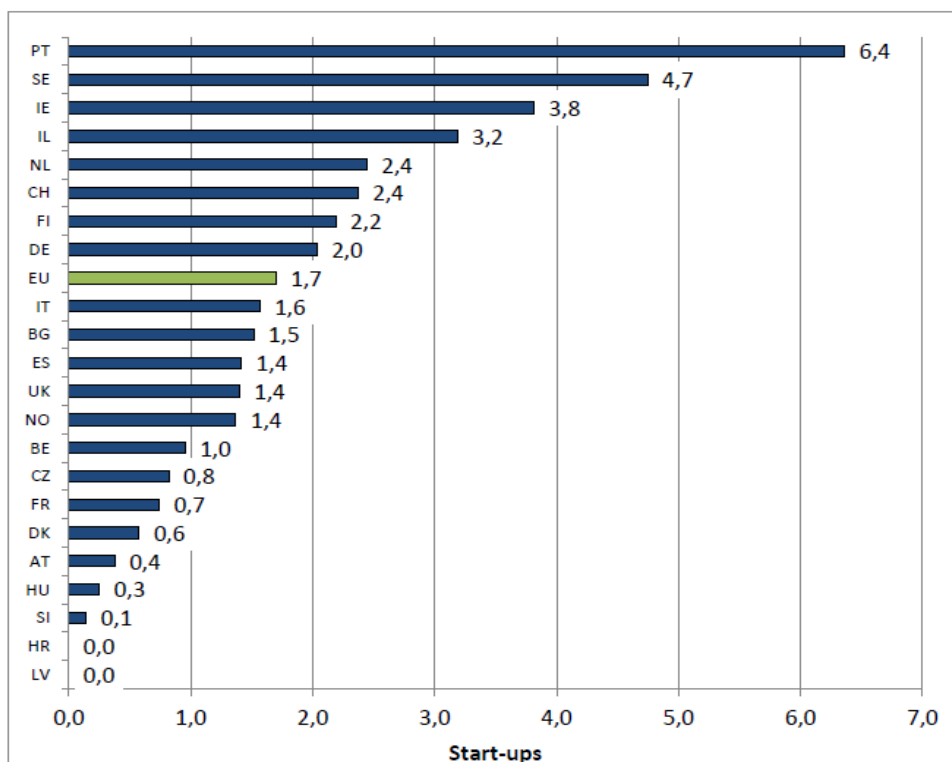
With 2 start-ups per 1,000 research staff, Germany ranks slightly above the EU average of 1.7 and slightly below Finland (2.2), see Figure 21. Focusing on the four big German RPOs, FhG created most start-ups between 2006 and 2014 (134 in total) followed by HGF (107), WGL (55) and MPG (41) (GWK, 2015)¹⁹⁸. In Germany, there are a number of measures supporting spin-off companies from universities and PROs (in particular *EXIST – Existenzgründungen aus der Wissenschaft*, see also 5.7.2. Policy Measures).

Focusing on innovation collaborations within the private sector, in the period 2010 till 2012 9.8% of innovative firms had innovation collaborations with suppliers, 8.7% with clients, 4.7% with competitors or firms in their own industry and 9.9% with consultants or commercial labs. The comparable numbers from the period 2006-2008 are 7% of innovative firms had collaborations with suppliers, 11% with clients, 5% with competitors and 6% with consultants and commercial labs.

Interestingly, R&D expenditures of independent scientific and technological service providers have increased by 13.3% between 2012 and 2013, employment in this sector increased by 16.1% (EFI, 2015). These trends point in the direction of an accelerated shift of innovation activities from internal R&D departments to external providers which can be seen as an indication for more open corporate innovation strategies characterised by increased usage of external knowledge and competence.

Figure 21: Number of start-ups per 1 000 of research staff per country. EKTIS 2011-2012 survey

Exhibit 3-33: Number of start-ups per 1,000 research staff by country, EKTIS 2011 and 2012 results combined



Source: MERIT, European Knowledge Transfer Indicator Survey 2011 and 2012.

¹⁹⁸ Start-ups created under a formal agreement and with the aim of exploitation of IPR belonging to the respective organisation.

5.7.2 Policy Measures

As the governance and funding of universities lie mostly with the Laender, the role of the Federal Government is primarily to provide funding in the form of programmes targeting knowledge transfer, public-private cooperation and entrepreneurship in a broad sense at universities, research organisations and companies. Most financial measures are funded by the Federal Ministry for Education and Research (BMBF) or the Federal Ministry for Economy and Energy (BMWi). Fostering science-industry links has been a policy priority in German R&D and innovation policy for many decades. A broad range of links are supported, including co-operations, clusters, networks, alliances, and public-private partnerships.

Germany has several policy initiatives which emphasize the geographical component of knowledge transfers between disciplines as well as R&D and innovation. They follow mostly the principle that colocation can provide conduits for knowledge flows based on social interaction, visibility and networks. Examples for such initiatives include Entrepreneurial Regions¹⁹⁹ ('Unternehmen Region') of BMBF. They encourage firms and universities in regional clusters to identify core competencies as well as their commercial exploitation. The geographical proximity can foster the efficiency of knowledge flows between science and industry because of direct interaction between scientists and the establishment of channels based on social networks. The initiative Twenty20 – Partnership for Innovation ('Zwanzig20 - Partnerschaft für Innovation') as a sub-measure of Entrepreneurial Regions creates a competition between interdisciplinary consortia including firms to develop joint innovation strategies. The initiative provides €500m until 2019 for developing joint innovation strategies based on a competitive assessment. Another prominent example is the Leading-Edge Clusters Competition²⁰⁰ ('Spitzencluster-Wettbewerb') from BMBF in which the Federal Government has invested €360m since 2008. 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. Moreover, entrepreneurship at universities and technology transfer activities are supported. The Expert Commission for Research and Innovation highlighted the Leading-Edge Cluster Competition as a good way to promote promising innovation clusters²⁰¹. A related approach was followed by the Networks of Competence ('Kompetenznetze') by BMWi. This scheme stimulated the establishment of sector networks to promote cluster building and international awareness of industrial networks in Germany and continues to exist today under the name 'go cluster'.

Other policy initiatives are directed at creating unified innovation strategies for particular topics such as electric mobility uniting major stakeholders from industry, trade unions, academia, technical organisations and research associations ('Nationale Plattform Elektromobilität'²⁰²) or encouraging collaboration with and among particular organisations, especially medium sized firms, the most prominent and longstanding initiative being the Central Innovation Program SME²⁰³ by BMWi which had disbursed €2.5b in funding until the end of 2012.

The Research Campus²⁰⁴ ('Forschungscampus') programme by BMBF contributes to knowledge circulation by enhancing 'Public-private Partnerships for Innovation' between universities, public research institutions and businesses which are aiming to develop new technologies in areas with high technological complexity and a great potential for radical

¹⁹⁹ <http://www.unternehmen-region.de/en/6499.php>

²⁰⁰ <http://www.bmbf.de/en/20741.php>

²⁰¹ EFI - Expertenkommission Forschung und Innovation (2010): Gutachten 2010, Gutachten zu Forschung, Innovation und technologischer Leistungsfähigkeit, http://www.e-fi.de/fileadmin/Gutachten/2010_engl.pdf

²⁰² <http://www.bmub.bund.de/themen/luft-laerm-verkehr/verkehr/elektromobilitaet/nationale-plattform-elektromobilitaet/>

²⁰³ <http://www.zim-bmw.de/>

²⁰⁴ <https://www.ptj.de/forschungscampus>; <https://www.bmbf.de/de/forschungscampus-oeffentlich-private-partnerschaft-fuer-innovationen-562.html>

innovation. One "campus" can be supported with up to €2m per year for a maximum period of 15 years.

Innovation Alliances²⁰⁵ ('Innovationsallianzen') are an instrument of public support to industrial innovation. Funding is provided by BMBF for strategic cooperation between industry and public research in key technology areas that demand a large amount of resources and a long time horizon, but promises considerable innovation and economic impacts. A contribution of €600m from the Federal Government has attracted more than €3b from the private sector.

Given that the Laender are responsible for university education, many initiatives related to encouraging science based entrepreneurship in Germany are due to their initiatives. These initiatives are often times in the form of incubators, entrepreneurship advisers or consultants. Initiatives in Bavaria include FLÜGGE²⁰⁶ or HOCHSPRUNG²⁰⁷. In Baden-Württemberg the programme Junge Innovatoren²⁰⁸ plays an important role in supporting younger scientists who engage in entrepreneurial activities. Other examples include the Humboldt-Innovation GmbH of Humboldt-University in Berlin which provides entrepreneurship consulting and services which have since 2005 resulted in more than 50 new firms; business plan competitions in the project "Spin off" of the research association of Mecklenburg-Vorpommern or the "Startercenter" of the University of Saarland which has hosted 255 newly founded firms since 1995²⁰⁹.

Additionally, BMBF funds research in universities of applied sciences²¹⁰ ('Fachhochschulen') with €40.7m in 2012 (€175m between 2006 and 2011). Research in universities of applied sciences is geared towards application and the needs of business.

Among the main research organisations, particularly the Fraunhofer Society (FhG) with its 67 institutes and research units focusses on the application of research and technology. FhG has a total budget of €2b in 2014 (GWK, 2015). Further, the German Federation of Industrial Research Associations (AiF) "Otto von Guericke"²¹¹ also plays a crucial role in connecting research and innovation. It manages a network of 100 research associations for applied research across business sectors and including research organisations and universities. It has roughly 50,000 business members and has provided public funding of €490m in 2013 mostly on behalf of BMWi.

Besides, there are programmes directly supporting knowledge transfer from science to business such as the Validation of Innovation Potentials (VIP)²¹² and the follow-up programme VIP+ which aims at supporting researchers at institutions of higher education and public research institutions to have their research findings reviewed at an early stage for technical feasibility, economic potential and ability to open up new fields of application. The VIP programme promoted respectively promotes around 140 projects with a budget of €150m in total. The HGF offers a similar scheme for researchers within their organisation. Helmholtz Validation Fund (HVF)²¹³ aims to bridge gaps between scientific findings and their commercial applications. €20m can be disbursed between 2011 and 2015. Currently 15 validation projects are receiving funds. The first validation project has been successfully commercialized and is financially profitable. With Helmholtz Enterprise²¹⁴ spin-offs are supported. The programme funded 83 projects between 2005 and 2013, and so far has helped to set up 50 new businesses. As for support for patenting, universities, companies and inventors can receive government

²⁰⁵ <http://www.bmbf.de/foerderungen/15121.php> (Example: Innovation Alliance Photovoltaik)

²⁰⁶ <http://www.fluegge-bayern.de/>

²⁰⁷ <http://www.hoch-sprung.de/>

²⁰⁸ <http://www.junge-innovatoren.de/>

²⁰⁹ BMBF, 2014, Bundesbericht Forschung und Innovation 2014, http://www.bmbf.de/pub/bufi_2014.pdf

²¹⁰ <http://www.bmbf.de/de/864.php>

²¹¹ <http://www.aif.de/en/about-aif.html>

²¹² <http://www.bmbf.de/de/2391.php>

²¹³ http://www.helmholtz.de/en/research/technologietransfer/foerderinstrumente/helmholtz_validierungsfonds

²¹⁴ http://www.helmholtz.de/en/research/technologietransfer/foerderinstrumente/helmholtz_enterprise/

support for protecting their intellectual property to make it safe to exchange with other partners in programs such as SIGNO²¹⁵ (Protection of ideas for commercial use) from BMWi, which is a funding initiative for institutions of higher education, businesses and inventors with a budget of €16.5m in 2012. More than 200 institutions have made use of SIGNO so far. SIGNO (until 2007: INSTI) ties into the TechnologieAllianz platform (see above) which offers intellectual property from public research for sale to private businesses.

Among support for university spin-offs, EXIST²¹⁶ is the most comprehensive programme. EXIST of BMWi was initiated in 1998 and is co-financed by the European Social Fund (ESF). It provides a range of instruments to entrepreneurs from academia. EXIST has been reformed in December 2014 with increases in available funds. Scholarships ('EXIST-Gruenderstipendium') increase by 25% and the included funds for investments cannot reach €30,000 instead of €17,000. Within EXIST-Forschungstransfer available investments in high tech projects increase from €70,000 to €250,000.

In November 2015, Fraunhofer launched the new online portal "Fraunhofer Innovationsforum". One of the new portal's main objectives is to further foster the exchange between business, industry and academia²¹⁷.

Several of the above mentioned initiatives and programmes form integral part of the German government's New High-tech Strategy.

5.8 Regulation and innovation

Recent efforts for assessing or reducing inadvertent effects of regulation in Germany on businesses have been centred around a newly enacted law for the reduction of bureaucratic burden ('Bürokratieentlastungsgesetz'). The law aims particularly at SMEs and aims lowering requirements for reporting and tax accounting²¹⁸. Parliament has approved the law in July 2015 (Deutscher Bundesrat, 2015) and the Federal Government has accompanied it with a commitment to offset new bureaucratic burdens on firms with the reduction of existing ones ('Bürokratiebremse')²¹⁹.

When assessing the impact of the new law on firms ex-ante, effects on innovation in firms is an explicit criteria (Kienbaum, 2015). However, the impact assessment finds no effect on innovation as reported by firms. There is no dedicated government department which is predominantly charged with overseeing the effects of regulation.

When firms in Germany are asked in the most recent Community Innovation Survey (CIS2012) to what degree costs from government regulation are obstacles to innovation activities, 33% indicate that it is not a relevant factor (ZEW, 2014). Then again, 20.5% of firms indicate that it is a highly important obstacle to innovation. This makes it an important obstacle for innovation but not a dominant one, e.g. 62% of firms in Germany indicate strong price competition as a highly important obstacle to their innovation activities. The share of firms in Germany which rate the costs of regulation as a highly important obstacle to innovation operate in financial services (66%), electricity, gas steam and air conditioning (65%), the manufacturing of pharmaceutical products (55%) as well as in the manufacturing of tobacco products (53%). For comparison, the share of firms in the manufacturing of motor vehicles, the largest R&D investing industry in Germany, is 15.5%.

²¹⁵ <https://www.ptj.de/signo-en>

²¹⁶ <http://www.exist.de/index.php>

²¹⁷ <http://www.fraunhofer.de/de/presse/presseinformationen/2015/November/fraunhofer-innovationsforum-wissenschaft-und-wirtschaft-online-vernetzt.html>

²¹⁸ <http://www.bmwi.de/DE/Themen/Mittelstand/buerokratieabbau,did=508704.html> (10/2015)

²¹⁹ <http://www.bmwi.de/DE/Presse/pressemitteilungen,did=719462.html> (10/2015)

5.9 Assessment of the framework conditions for business R&I

The framework conditions for business R&I in Germany are generally well functioning. They have supported a continuous, multi-year expansion of business R&D investment as well as an increase in non-R&D innovation expenditures (e.g. for market introduction) (European Commission, 2015c). The main research organisations fulfil a vital role within the German R&I system addressing all components of the system from basic research to applied technologies. They also seem well positioned to react flexibly to changes in technological opportunities and market requirements. The extension of the Pact for Research and Innovation which provides them with reliable, annual budget growth is a positive sign. Besides, the Initiative for Excellence has provided a positive dynamic for ambitious university research in Germany which is likely to result in positive spill overs for business R&I in the future.

In general, supply and demand side policies in Germany are co-evolving as evidenced by the new high-tech strategy (BMBF, 2014d) which combines both elements and sets priorities which are consistently guiding further policy strategies and plans, e.g. the Leading-Edge Cluster Competition. Systemic evaluation of R&I frameworks in Germany, particularly through the Expert Commission for Research and Innovation (EFI) provides meaningful feedback and assessments. R&I policy in Germany has proven to be sensitive to many important parts of such evaluation results, e.g. in changing the constitution (Art. 91b GG 'Grundgesetz') for a permanent partnership of federal and Laender governments in funding universities.

Among the aspects of framework conditions for business R&I which have the most potential for improvement in Germany are:

- SMEs ('Mittelstand') are a crucial part of the German economy and R&I system. Accordingly, many policy programmes are in place to support the R&I in this particular group of firms in Germany (e.g. ZIM, AiF). For these reasons, the decline of innovation expenditures of SMEs in Germany (EFI, 2015) as well as the decline in SMEs with product/process innovation (-3%) as well as marketing/organisational innovations (-5.4%) (European Commission, 2015c) deserves particular attention and a more fine grained understanding of cause and effect relationships.
- A comparatively large share of engineers, mathematicians and natural scientists in Germany will retire over the next ten years. This challenges the German R&I system to train their successors as central contributor to R&I in Germany (Baethge et al., 2015). The increase in new students in the relevant MINT programmes of universities in Germany is a good sign as well as the increasing investment in improving the quality of higher education teaching with an emphasis on lowering drop-out rates. It remains to be seen whether these newly trained scientists and engineers will be able to replace their retiring counterparts or even absorb some of their tacit knowledge stock built from experience.
- The size of the venture capital market in Germany is low when compared with other innovation leader member states and declining as a share of GDP (European Commission, 2015c). EFI (2015) concludes that the provision of additional budgets from government may be counteracted by unfavourable tax laws, e.g. the treatment of forward carried deficits for new investors or value added taxes on fund management services, as well as the absence of liquid capital markets on which venture capital investors could sell their investments efficiently. They suggest a pan-European solution for the latter with the creation of a new stock exchange segment which could provide capital market access for young firms across Europe without suffering from liquidity constraints of national capital markets. Hence, venture capital investors would have efficient exit options for their initial investments.

6. Conclusions

6.1 Structural challenges of the national R&I system

The EU Innovation Union Scoreboard 2015 indicates that the German R&I system performs well within Europe. Together with Sweden, Denmark and Finland, Germany forms the group of innovation leaders among the EU member states indicating that their combined innovation index is at least 20% above the average of EU-28 (European Commission, 2015c). However, the innovation index of Germany has declined slightly in 2014. Consequently, Germany has traded places with Finland, finishing 4th among all EU member states. In relative terms, Germany used to perform 27% above the average of EU-28 in 2012 but this advantage has been reduced to 22% in 2014.

While Germany had significant improvements along several dimensions of the innovation scoreboard in 2014 such as the license and patent revenues from abroad (+19%), non-R&D innovation expenditures (+6.3%) as well as international, scientific co-publications (+6%), its position has declined in others. Most importantly, the share of sales that firms could create from innovations has declined (-5.5%). This development coincides with fewer SMEs creating product or process innovations (-3.1%) as well as marketing or organisational innovations (-5.4%). However, Germany continues to perform significantly above EU averages along both SME indicators. The situation for the indicator of venture capital investments is different. It is one of the few dimensions in which Germany performs significantly (33%) below EU averages and the level has declined in 2014 by 5.2%.

Germany differs significantly from the other innovation leader member states because of its size and federal structure as well as the industry composition of the economy. The particular situation of the German R&I system provides many opportunities which may turn into challenges if they are not addressed. Based on this report, the EU Innovation Scoreboard 2015 (European Commission, 2015c) and the report of the Expert Commission on Research and Innovation (EFI, 2015) the following major opportunities and challenges can be identified:

- Innovation in SMEs
SMEs ('Mittelstand') are of particular importance for the German economy as well as its R&I system (European Commission, 2014a). Several indicators point in the direction that their engagement in R&I is slowing down, albeit from a high level. While large companies (more than 500 employees) have continuously increased their hiring of scientists and engineers between 1999 and 2010, medium sized firms (100 to 500 employees) had only slow growth of hiring in this group of highly qualified employees while small firms (fewer than 100 employees) experienced even a slight decline (EFI, 2015). Similarly, innovation expenditures (adjusted for sales) have increased in large firms between 1995 and 2012 while they have declined for SMEs (EFI, 2015). SMEs which engaged only occasionally in R&D have been particularly likely to reduce their innovation expenditures. Accordingly, fewer SMEs become innovators along all dimensions, products, process, marketing or organisational innovations (European Commission, 2015c).
- Size of the market for venture capital
The market for venture capital is consistently and significantly smaller than in other innovation leader member states of the EU (European Commission, 2015c). Several policies are in place in which government provides funds for co-investments with venture capital investors (e.g. ERP-Startfonds) or limits their potential losses (e.g. INVEST – Zuschuss Wagniskapital) (see section 5.4 of this report for details). However, EFI (2015) provides a number of framework conditions which limit the size of the market for venture capital in Germany. Among those is the taxation system which can lower the attractiveness of investments in high-tech start-ups, e.g. the treatment of forward carried deficits for new investors, or make fund management comparatively costly, e.g. value-added tax on funds management services. Besides, few institutional investors

exist which could serve as large, anchor investors which signal the quality of investments to venture capital firms. Finally, the absence of a liquid stock market segment for young, high-tech firms limits the exit options for venture capital investors at the end of their investment. EFI (2015) envisions a pan-European capital market segment to avoid illiquidity from fragmented national market solutions.

- Mix and replacement of human resources for innovation

The German R&I system faces challenges from replacing retiring skilled engineers and scientists as well as changes in the way in which future human resources and scientists are trained. First, a relatively large proportion of engineers, mathematicians and natural scientists in Germany approaches retirement (Baethge et al., 2015). Hence, more scientists and engineers will be required to replace them. The increase in student intake at universities in general as well as in MINT topics in particular is a positive sign. However, high drop-out rates in the latter remain a significant challenge (Stifterverband, 2015b). Second, the German R&I system has traditionally benefitted from a labour force in which innovation is not exclusively the task of university trained scientists and engineers. Instead, a broad group of employees with human capital acquired through apprenticeships, on the job training and professional experience ('Facharbeiter') has complemented scientific research and discovery in crucial ways. However, in recent years preferences of school students have shifted towards academic skill development in universities. It remains unclear what the consequences for the performance of the German R&I system are (EFI, 2014). Current policy approaches aim at counterbalancing the change in educational preferences among young adults by making vocational trainings more attractive or stepping stones towards further education at universities.

- Strategy implementation

The German R&I system has undergone an important structural change when federal and Laender governments agreed to change the constitution (Art. 91b GG 'Grundgesetz') for a permanent partnership of federal and Laender governments in funding universities. The principle intention is to use such collaborations between federal and Laender governments to broaden the portfolio of excellent research in Germany by enabling universities to develop distinct profiles. However, it remains to be seen how the new opportunities can be realized and balanced with the need for unanimous agreement of all Laender governments to particular engagements of the Federal Government in a few of them. Similarly, the Federal Government has outlined a comprehensive new High Tech Strategy as well as a Digital Agenda 2014-2017. EFI (2015) welcomes both strategies but asks for the definition of milestones, monitoring and evaluation so that progress can be assessed and learning enabled.

Table 6: Summary table for structural challenges of the national R&I system

Challenge	Policy measures / actions addressing the challenge	Assessment in terms of appropriateness, efficiency and effectiveness
Innovation in SMEs	New High-Tech Strategy Digital Agenda 2014-2017 Central Innovation Programme for SMEs (ZIM) SME participation in cross-cutting or targeted research programmes (eg. via SME-innovativ) New SME concept "Give Way to SMEs" of BMBF	Trend deserves high priority and political attention Many SME targeted policies are in place More research is required into cause and effect relationships before policies can be adjusted or refined
Size of market for venture capital	ERP-Startfonds INVEST – Zuschuss Wagniskapital New venture capital fund with EIF (€500m)	Government funding is increasing Efforts to create sizable institutional investor through EIF fund Change of tax regulation on carried forward losses is stalled Unintentional consequences from regulatory changes or in taxation cannot be ruled out Creation of European stock market segment for young, high-tech firms has so far little political momentum
Mix and replacement of human resources for innovation	Extension of Pact for Higher Education with dedicated funds for reducing drop-out rates Pact for Teaching Quality Simplification of recognition of diplomas from abroad Reform of the law for the "Promotion of Advancement through Training" Support for further education	Increase in student intake at universities and in MINT topics Improved recognition of foreign degrees and diplomas Improvements in teaching quality Improvements in opening university education for students with vocational training
Strategy implementation	Agreement on extension of pacts between federal and Laender governments Comprehensive evaluation of Leading-Edge Cluster Competition Start of evaluation process for Initiative for Excellence Establishment of the German Council for Scientific Information Infrastructures	Positive commitment to meaningful, comprehensive evaluation Design of collaboration agreements between federal and Laender governments remains unclear Milestones of strategies remain unclear

6.2 Meeting structural challenges

The main issues for the German R&I system laid out in the previous section are complex in nature and require integrated, long term policy solutions. The current mix of R&I policies in Germany outlined in this report shows that policy makers are aware of the issues. The challenges are reflected to varying degrees.

With regard to addressing the slowdown of innovation in SMEs, Germany has multiple policies in place which target particularly this group of firm. Innovation in SMEs certainly has the attention of policy makers in Germany. The topic is a central part of virtually every major R&I strategy such as the New High-Tech Strategy (BMBF, 2014d) or the

Digital Agenda 2014-2017 (BMW, 2014a). Programmes are in place to address the needs of SMEs. These include in particular the Central Innovation Programme for SMEs (ZIM). The BMBF in January 2016 issued a new SME concept "Give Way to SME – the Ten-Points-Programme of BMBF for More Innovation in Small and Medium-Sized Enterprises" ('Vorfahrt für den Mittelstand – Das Zehn-Punkte-Programme für mehr Innovation in kleinen und mittleren Unternehmen') and opened a wider discussion with stakeholders. The programmes have significant funds and flexible, decentralized forms of organisation to address the needs or changing needs of SMEs. The particular drivers underlying the slowdown in innovation activities of SMEs require further investigation (EFI, 2015). Initial observations point towards a drop out of SMEs from innovation activities which engaged in R&D only selectively and lacked stable structures. Existing policy programmes may not reach this particular group of firms because they lack the innovative and absorptive capacities to identify research opportunities and engage with external partners such as universities. In sum, this particular challenge requires more detailed insights into the competitive situation of SMEs in general and their decision making for investing in innovation activities as a basis for policy development and refinement.

Focusing on the size of the market for venture capital, the Federal Government has been active in increasing available funds for leveraging venture capital investments (e.g. ERP-Startfonds) or reducing risks for early stage investors and business angels (e.g. INVEST – Zuschuss Wagniskapital). The effectiveness of these instruments may have been slowed down by inadvertent uncertainties about tax treatment or the stalled reform of the capital gains tax (see section 5.4 of this report for details) (EFI, 2015). The latter holds significant potential for the German venture capital market because it would make investments in young, R&D intensive firms which are likely to have significant forward carried deficits. While the announcement of a new venture capital fund of the Federal Government with the European Investment Fund (EIF) with a volume of €500m is a positive sign for creating a sizable "anchor" investor, most considerations of the Expert Commission for Research and Innovation aim at preventing a worse situation for the German venture capital market by cautioning against unintended consequences of policy changes, e.g. by stricter regulation for the investment opportunities of insurance companies (EFI, 2015). The suggestion of creating exit options for venture capital investors through a pan-European stock market segment for young, high-tech firms holds promise but has currently little political momentum.

With regard to the challenge from the changing mix and the increased need for replacement of human resources for innovation, the Federal Government has been active. Focussing on replacement needs, the intake of students at universities has increased in general as well as for MINT topics. With the extraordinary effects on student numbers, such as the abolishment of mandatory military service, subsidising, universities should have new flexibility to improve quality. In this regard, the extension of the Pact for Higher Education ('Hochschulpakt 2020') through federal and Laender governments provides necessary funds. It is also a positive sign that with the extension of the pact, teaching quality and the reduction of dropout rates among students has become an explicit goal with dedicated funding. Similarly, the Pact for Teaching Quality ('Qualitätspakt Lehre') in higher education provides important stimuli for improved teaching at universities. The leadership of universities indicates and improved situation of universities in Germany per se (Stifterverband, 2015a), other studies indicate that university education in Germany is improving but slowly (Stifterverband, 2015b). Besides, the Federal Government has improved procedures to make it easier for foreign professionals to have their degrees and diplomas accredited in Germany through the reform of the law for simplifying such recognition procedures ('Gesetz über die Feststellung der Gleichwertigkeit von Berufsqualifikationen, Berufsqualifikationsfeststellungsgesetz - BQFG'). This measure eases the access for foreign professionals for the German labour market. In sum, it is not foreseeable to what degree experienced scientists and engineers will be replaceable or to which degree the

re-newel of part of the skill based will also bring new opportunities for the German R&I system.

Apart from these replacement needs, the German R&I system faces a change in preferences for educational careers with university education becoming the increasingly preferred career strategy for most high school students. The Bundestag has passed legislation on a reform of the law for the "Promotion of Advancement through Training" ('Aufstiegsfortbildungsförderungsgesetz,' AFBG) in March 2016 and the law will be enacted in August 2016. This change will make vocational education more attractive as it provides funds for further education. The share of dual university careers (combining work with university education) is still small but increasing (BMBF, 2014b). Current policies aim at increasing the attractiveness of vocational training ('Facharbeiter') but moving away from envisioning it less as the final step of professional training and instead as a stepping stone to further, academic qualification. This appears to be an adequate, modern re-interpretation of the successful 'Facharbeiter'-model.

Finally, the German R&I system faces the challenges of how to manage the implementation of new opportunities from continuous involvement of the Federal Government in university funding (following the change of constitution, article 91b GG) as well as from the implementation of the new high-tech strategy as well as the Digital Agenda 2014-2017. Focussing on the collaboration between federal and Laender governments, the parties have sent positive signals to their commitment to excellence in R&I in Germany as well as constructive dialogue. This is evidenced by agreement to extend the Pacts for Research and Innovation as well as the Pact for Higher Education until 2020. Federal and Laender governments have also in principle agreed to an extension of the Initiative for Excellence which will expire in 2017. Especially the process of choosing elite universities as part of the Initiative for Excellence indicates the awareness for strengthening excellence since the 11 elite universities are located in only six of the 16 Laender. Besides, an independent, international evaluation commission has also been established to evaluate and report on the current round of the Initiative for Excellence.

This follows a positive trend for comprehensive and meaningful evaluation as evidenced by the evaluation of the Leading-Edge Cluster Competition ('Spitzencluster-Wettbewerb') which the Expert Commission for Research and Innovation (EFI) recommends as a template for future evaluations (EFI, 2015). Structurally, the establishment of a German Council for Scientific Information Infrastructures ('Rat fuer Informationsinfrastrukturen', RfII) as part of the Digital Agenda 2014-2017 in November 2014 consisting of representatives of government, users and public life creates an additional institution to consult on implementation issues. Similarly, the creation of High-Tech Forum in 2015 as part of the new high-tech strategy is a positive signal. The forum consists of 20 high-level representatives from academia, industry and civil society. Nevertheless, the progress towards planned milestones within the central R&I strategies remains to be seen.

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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)
BMI	Bundesministerium des Inneren
BMU	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit
BMVBS	Bundesministerium für Verkehr, Bau und Stadtentwicklung
BMVg	Bundesministerium der Verteidigung
CDU	'Christlich Demokratische Union'
CHE	Centre for Higher Education
CEWS	Center of Excellence Women and Science
C&C	Charter & Code
ERA	European Research Area
DAAD	Deutscher Akademischer Austausch Dienst (German Academic Exchange Service)
D-A-CH	Deutschland – Austria – Switzerland
DG	Directorate General (of the European Commission)
DESY	Deutsches Elektronen Synchrotron (German electron synchrotron)
DFG	Deutsche Forschungsgemeinschaft (German Research Foundation)
DWIH	Deutsche Wissenschafts- und Innovationshäuser
EC	European Commission
ECB	European Central Bank
EFI	Expertenkommission Forschung und Innovation (Experts Commission for Research and Innovation)
EIB	European Investment Bank
EPO	European Patent Office
ERA-NET	European Research Area Network
ERDF	European Regional Development Fund
ESIF	European Structural and Investment Fund
ESF	European Social Fund
ESFRI	European Strategy Forum on Research Infrastructures
ETP	European Technology Platform
EU-28	European Union including 28 Member States
FDP	'Freie Demokratische Partei – Die Liberalen'
FhG	Fraunhofer-Gesellschaft (Fraunhofer Society)

FAIR	Facility for Antiproton and Ion Research
FP / FP7	European Framework Programme for Research and Technology Development / 7th Framework Programme
GBAORD	Government Budget Appropriations or Outlays on R&D
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on R&D
GG	Grundgesetz (Germany's Basic Law)
GOVERD	Government Intramural Expenditure on R&D
GWK	Gemeinsame Wissenschaftskonferenz (Joint Science Conference)
HEI	Higher education institutions
HERD	Higher Education Expenditure on R&D
HES	Higher Education Sector
HGF	Helmholtz-Gemeinschaft Deutscher Forschungszentren (Helmholtz Association)
HRK	Hochschulrektorenkonferenz (German Rectors' Conference)
HRST	Human Resources in Science and Technology
HTS	High-Tech Strategy
ICT	Information and Communication Technology
ID	Identification
IGF	Industrielle Gemeinschaftsforschung (industrial collective research)
IP / IPR	Intellectual Property / Intellectual Property Rights
ISCED	International Standard Classification of Education
IU	Innovation Union
IUS	Innovation Union Scoreboard
KET	Key Enabling Technologies
MINT	Mathematics, Information technology, Natural sciences and Technology
MPG	Max-Planck-Gesellschaft (Max Planck Society)
NTBF	New Technology Based Firms
NRP	National Reform Programme
NRW	North Rhine Westphalia
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
RIS3	Regional and/or National Research and Innovation Strategies on Smart Specialisation
RIS	Regional Innovation System
R&I	Research and Innovation

SB	Scoreboard (of not otherwise mentioned here stands for "EU Industrial R&D Investment Scoreboard")
SPD	Sozialdemokratische Partei Deutschlands
S&E	Science and Engineering
S&T	Science and technology
SME	Small and Medium Sized Enterprise
VC	Venture Capital
VDI	'Verein Deutscher Ingenieure' (Association of German engineers)
VIP	Validation of Innovative Potential of Scientific Research
WGL	Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz (Leibniz Association)
WR	Wissenschaftsrat (German Council of Science and Humanities)
ZIM	Zentrales Innovationsprogramm Mittelstand (Central Innovation Programme for SMEs)

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Annex 1 – List of the main research performers

Universities chosen by the 2012 round of the Initiative for Excellence²²⁰

Name of university
RWTH Aachen
Freie Universität Berlin
Humboldt-Universität zu Berlin
Universität Bremen
Technische Universität Dresden
Ruprecht-Karls-Universität Heidelberg
Universität zu Köln
Universität Konstanz
Ludwig-Maximilians-Universität München
Technische Universität München
Eberhard Karls Universität Tübingen

EPO filings by university applicants, 2008-2010, Top 10 in Germany

Name of university	Number of EPO filings 2008-2010
Karlsruher Institut fuer Technologie	121
Universitaet Freiburg (i.Br.)	121
Technische Universitaet Dresden	76
Technische Universitaet Berlin	72
Technische Universitaet Muenchen	70
Universitaet Heidelberg	63
Universitaet Erlangen-Nuernberg	59
LMU Muenchen	58
Universitaet Muenster	53
Charite - Universitaetsmedizin Berlin	50

Source: Dornbusch and Neuhausler (2015)

Top 10 firms by total R&D expenditures in Germany 2013

EU rank	Name	R&D 2013 (€million)	R&D intensity (%)
1	VOLKSWAGEN	11743.0	6.0
2	DAIMLER	5379.0	4.6
3	BMW	4792.0	6.3
5	ROBERT BOSCH	4653.0	10.1
6	SIEMENS	4556.0	6.0
12	BAYER	3259.0	8.1
14	BOEHRINGER INGELHEIM	2743.0	19.5
16	SAP	2282.0	13.6
19	CONTINENTAL	1918.6	5.8
20	BASF	1849.0	2.5

Source: European Commission (2014c)

²²⁰ http://www.dfg.de/download/pdf/foerderung/programme/exin/ergebnis_bewilligungsausschuss_exin_120615.pdf

Annex 2 – List of the main funding programmes

Name of the funding programme	Timeline	Budget in €m	Target group
Initiative for Excellence - Graduate Schools	2012-2017	360	Universities
Initiative for Excellence - Excellence Clusters	2012-2017	1,364.4	Universities
Initiative for Excellence - Future Concepts	2012-2017	690	Universities
Leading-Edge Cluster Competition	2007-2017	600	Regional collaborations of universities and firms
Validation (VIP) VIP+	2010-2017 Continuous	150 in total n.a.	Higher education and research bodies
Research Campus	Start in 2012 (maximum period of 15 years)	up to €2m per year per campus	Universities and firms on strategic basic research
DFG Research Grants	Continuous	2,313.8 (2011-2013)	Individual researchers holding PhD
Emmy Noether-Programme	Continuous	203 (2011-2013)	Individual researchers holding PhD
Heisenberg-Programme	Continuous	52.8 (2011-2013)	Individual researchers holding PhD
Reinhart Koselleck-Projects	Continuous	30.2 (2011-2013)	Individual researchers holding PhD
Clinical Trials	Continuous	35.3 (2011-2013)	Individual researchers holding PhD
Research Centres	Continuous	125.9 (2011-2013)	Universities
Collaborative Research Centres („Sonderforschungsbereiche“)	Continuous	1,675.2 (2011-2013)	Universities
Priority Programmes	Continuous	592.7 (2011-2013)	Universities
Research Groups	Continuous	516.6 (2011-2013)	Universities
Graduate Colleges	Continuous	458.6 (2011-2013)	Universities
TechnologieAllianz	Continuous	n.a.	Universities and research organisations
EXIST – Existenzgründung aus der Wissenschaft	Continuous	67 (2014)	Start-ups from science
High-tech Start-Up Fund	Continuous	investment endowment of €272m (since 2013, has been entirely financed by the ERP Special Fund; BMWi: 5)	Innovative firms
ERP-Startfonds	Continuous	n.a.	Technology-intensive start-ups
INVEST – Zuschuss Wagniskapital	Continuous	23 (2014)	Technology-intensive start-ups
IKT Innovativ	Continuous	n.a.	IT start-ups
Unternehmen Region	Continuous	n.a.	Regional firms and science

Name of the funding programme	Timeline	Budget in €m	Target group
Zwanzig20	2012-2019	500	Regional firms and science
Central Innovation Programme for SMEs (ZIM)	Continuous	513 (2014)	SMEs
ERP-Innovation Programme	Continuous	Loans provided 1.329 (2014)	SMEs
SME (KMU.)innovativ	Continuous	100 (2012)	SMEs
Innovation vouchers	Continuous	n.a.	SMEs
SIGNO	Continuous	n.a.	Firms

Sources: DFG (2015a), DFG (2015b), BMWi (2015a) and BMBF (2014c).

Annex 3 – Evaluations, consultations, foresight exercises

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