RESEARCH, INNOVATION
AND TECHNOLOGICAL
PERFORMANCE IN GERMANY

COMMISSION OF EXPERTS
FOR RESEARCH
AND INNOVATION

EFI

REPORT

2008 2009 2010
2011 2012 2013
2014 2015 2016
2017 2018 2019

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The Expert Commission wishes to emphasise that the positions expressed in the report do not necessarily represent the opinions of the aforementioned persons.

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This report is also the result of the highly competent and dedicated work of the staff of the Expert Commission's coordination office and the staff of the Commission members.

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CONTENTS

FOREWORD

At the start of the new parliamentary term, the challenges for Germany's R&I policy can be subsumed under the following question: After many years of fairly successful catching-up processes, are efforts in the fields of education, science and innovation going to be continued – or will political stakeholders rest on their laurels?

Several passages in the government parties' coalition agreement give rise to the fear that investments in research and innovation are indeed fading into the background. From an innovation policy point of view, the coalition agreement is considered a disappointment, as it does not include key concepts expressly mentioned in the respective election programmes of the government parties. These include the revision of the Federalism Reform and the introduction of R&D tax credits in particular. Other passages of the agreement do indeed address major challenges, while also suggesting suitable measures for mastering these challenges. Thus, e.g. the support of start-up businesses receives special attention in the coalition agreement.

The Commission of Experts for Research and Innovation addresses some of the key issues of German R&I policy in the individual chapters of its 2014 Report. The Expert Commission outlines the need for action, based on policy measures deemed suitable for securing and advancing the results accomplished to date through the Higher Education Pact, the Excellence Initiative and the Pact for Research and Innovation (Chapter A 1). The Expert Commission calls for a more efficient approach to research and innovation policy and a stronger and smarter use of evaluations (Chapter A 2). The Expert Commission stresses the competitive advantages of Germany's functioning vocational education system and its impact on the innovation system: in this regard, innovation potential can be tapped especially at the interface of vocational and academic training (Chapter A 3). Germany can only play a leading role in the process of international knowledge intensification if it continues its efforts also in the fields of cutting-edge technology and knowledge-intensive services (Chapter A 4). A study on internationalisation trends in research and development (Chapter A 5) suggests that German businesses are increasingly conducting their R&D in cutting-edge technology abroad. In Chapters A 6 and A 7, the Expert Commission addresses current debates on electromobility and the Renewable Energy Resources Act (EEG) and reviews the effects of measures employed to date from an innovation perspective. With regard to both topics, the Expert Commission's findings are rather sobering.

The core chapters of the 2014 Report discuss key challenges for Germany's R&I policy. An international comparative study on university medicine (Chapter B 1) provides suggestions for improving Germany's performance in this important area of research and innovation. Top performance in research requires a critical size of university medicine locations and thus a certain regional concentration of research. Another key challenge for German medical research lies in creating internationally competitive working conditions for talented scientists and medical staff.

Chapter B 2 assesses the international mobility of research scientists and inventors. Here it can be demonstrated that Germany, despite its progress in several fields, continues to lose too many scientists to locations abroad. One of the main tasks for German R&I policy remains to be the acquisition and recovery of particularly talented scientists by providing internationally competitive research conditions. This task can only be accomplished if the German x&I system is also developed further in the top segment and becomes again more attractive, especially for the best international research scientists.

In Chapter B 3, the Expert Commission discusses one of the German innovation system's main shortcomings: the lack of competitiveness in the field of information and communication technologies (ICT) – an industry sector that also plays a key role for many other technologies and industries. The Expert Commission advocates the need to put the Digital Agenda, which is outlined in the coalition agreement, into concrete terms.

Chapter B 4 discusses the role of women in the innovation process, an area in which Germany has a great need to catch up. The Expert Commission believes that the potential of well-trained and highly skilled women in particular must be exploited and retained for research and innovation to a much greater extent.

A review of the chapters clearly demonstrates that the same issues keep reappearing, and thus the Expert Commission keeps recommending similar actions: especially in the area of top-level research, Germany will have to increase the attractiveness of its financial and regulatory framework. As a result, medical research could be further strengthened, research in the field of ICT could be made more competitive, and the utilisation of international researcher mobility for innovation could be improved across all industry sectors. All of the measures recommended in this report have multiple effects and should be treated with the highest priority as they will pay off in multiple ways. Therefore, postponing these issues further into the future will be particularly costly.

New government constellations also provide new opportunities. This is particularly the case as the Federal Government has now the chance to correct a partially unsuccessful Federalism Reform in agreement with the Länder governments, i.e. the federal states. The Commission of Experts for Research and Innovation hopes that the recommendations made in the 2014 Report will contribute to developing the German research and innovation system both swiftly and systematically.

Berlin, 26 February 2014

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SUMMARY

SUMMARY

CURRENT DEVELOPMENTS AND CHALLENGES

A 1 FURTHER DEVELOPING THE REFORM INITIATIVES

Following the expiry of the Higher Education Pact, the Excellence Initiative and the Pact for Research and Innovation, a package of measures will have to be developed over the next few months to further support tertiary education institutions and non-university research organisations.

Basic funding of tertiary education institutions should be strengthened. In this regard, it is imperative to amend Article 91b of the German constitution so as to re-enable the Federal Government to support tertiary education institutions at an institutional level. In the medium term, any projects funded by the public sector should also be granted full-cost funding. The expected decline in student numbers should be taken advantage of to improve the quality of teaching and research: the student/teacher ratio and teaching commitments of professors in tertiary education institutions have to be adapted to meet international standards. The Expert Commission recommends providing special support to the best performing tertiary education institutions in particular, in order to strengthen top-level research and thus the international competitiveness of the German research system.

The Federal and *Länder* governments should fund non-university research institutions based on a uniform financing key of approximately 70:30. The Expert Commission would like to emphasise that the performance of non-university research organisations can only be enhanced if an increase in funding is granted not only in nominal, but also in real terms.

A 2 PROMOTING INNOVATION MORE EFFICIENTLY THROUGH THE EVALUATION OF POLICY MEASURES

Scientifically valid evaluations of innovation policy measures are an important basis for well-founded economic policy decisions. Evaluations facilitate the tailoring of individual measures for achieving the desired results based on an efficient use of resources. Evaluations thus contribute to promoting research and innovation in Germany more efficiently. Several other countries are more advanced than Germany when it comes to applying and institutionalising such evaluations. The Federal Republic should align itself to these best practice examples and promote the use of scientifically well-founded evaluations.

To institutionalise well-founded evaluations, the Expert Commission recommends systematically expanding centralised centres of competence, an approach that has been initiated in some of the ministries, while also creating relevant data centres. It is crucial to design the evaluation of policy measures transparently. The data required for a well-founded analysis should be collected parallel to the implementation of a project. Based on the principle of transparency, data should also be made available to scientists to enable them to replicate and review evaluation results. To facilitate the commissioning of evaluations, 0.5 percent of the relevant ministry's project budget should be allocated to the centralised evaluation bodies.

THE RELEVANCE OF TERTIARY EDUCATION AND VOCATIONAL EDUCATION AND TRAINING FOR INNOVATION A 3

The German production and innovation model, particularly in the industrial sector, is based on a specific combination of highly qualified university graduates – mostly from natural sciences and engineering – and highly skilled workers from the dual vocational education system.

To avoid jeopardising this inherent strength, investments in retaining and developing the attractiveness of vocational training have to be continued. Talented, ambitious graduates from vocational training should be provided with clear-cut career options based on individual development opportunities and an increased permeability between different educational tracks. Future goals for the German educational system should focus on an optimal mix of different types of education and flexible individual educational paths, rather than the ratio of university graduates. To achieve these goals, new education indicators will have to be developed.

Based on the foreseeable decline in the numbers of graduates from compulsory schooling, the financing formulas for upper secondary and tertiary education should in the future focus on schooling quality and learning achievements, rather than focussing on student enrollment numbers. Regular external achievement tests should be conducted at all levels of the general school system. These should aim to document the individual learning progress in particular. The results of these assessments should be made publicly available at school level. Such assessment tests should be combined with an increase in autonomy for schools in terms of allocating their resources.

STRUCTURE AND DEVELOPMENT OF THE KNOWLEDGE ECONOMY A 4

A structural change towards the expansion of the knowledge economy can be observed on a global scale. The knowledge economy includes research-intensive industries and knowledge-intensive services. Germany tends to show strength in the area of research-intensive industries, but continues to show deficits in knowledge-intensive services. Germany's strengths in the field of high-value technologies should be supplemented by complementary developments in the field of cutting-edge technologies and knowledge-intensive services.

Germany's research and innovation policy needs to significantly improve conditions for cutting-edge technologies. To achieve this, it will be essential to enhance efforts in the fields of entrepreneurship, innovation and growth financing, as well as R&D tax credits. Even more than in the past, businesses in Germany should focus on increasing productivity by utilising the latest information and communication technologies (ICT).

Furthermore, the expansion of the knowledge economy should not be conducted in isolation from the upstream and downstream sectors of the economy, but should also be utlilised to promote spillover effects and productivity gains in the non-knowledge-intensive industries of the German economy and the public sector.

A 5 INTERNATIONALISATION OF RESEARCH AND DEVELOPMENT

In recent years, the internationalisation of research and development (R&D) of German companies has increased significantly. Yet, when it comes to cutting-edge technology, it is of concern that German companies are increasingly performing their R&D activities abroad. In the field of cutting-edge technology, Germany is losing a considerable number of scientists and inventors to other countries (cf. Chapter B 2). German companies, especially those in ICT, in turn are relocating their research and development facilities in search of such cutting-edge expertise in precisely those countries. These developments thus mutually reinforce each other, thereby weakening Germany as an innovation location in the long term.

It is therefore of central importance for Germany's R&I policy to retain talented innovation professionals, whether it is scientists or inventors, in Germany, or to recover them from abroad, respectively. Measures relating to such efforts (cf. Chapters B 2 and B 3) must be coupled with incentives in order for international companies to become active in the field of cutting-edge technologies in Germany.

A 6 ELECTROMOBILITY: SOME ACHIEVEMENTS, AND A LOT MORE TO DO

The development of the transport sector towards more environmentally friendly electromobility is regarded as crucial for the sustainability of future energy systems. Since 2009, stakeholders from politics and industry have significantly increased their efforts to promote electromobility. The aim is to develop Germany as the lead market and lead supplier for electromobility. However, at this point in time, it is not possible to conclusively evaluate the effectiveness of research funding programmes.

In recent years, efforts to introduce electromobility have been focussed on battery-powered vehicles. In addition to high-performance batteries, fuel cells could also be established as a propulsion technology for electric motors. Research funding policies should not discriminate between research in the fields of high-performance batteries and fuel cells. Existing programmes should be reviewed for effectiveness and future potential in order to decide how built-up expertise can be retained in Germany and how a market launch may be successfully supported. Electromobility also represents an important field of application for ICT. A close integration of research programmes on electromobility and ICT should be conducted as part of the Federal Government's Digital Agenda.

THE EEG FROM AN INNOVATION POLICY PERSPECTIVE A 7

The Renewable Energy Sources Act (EEG) is one of the key instruments of German climate and energy policy. Yet, with the European emissions trading system (EU ETS) in place, which defines a fixed ceiling for CO_2 emissions across European energy-intensive industries, the EEG does not lead to more climate protection, but merely induces additional cost. Since the argument of climate protection does not qualify, the question arises whether the EEG does at least stimulate innovation. However, empirical studies do not find a measurable impact of the EEG on innovation.

In the view of the Expert Commission, a continuation of the EEG can therefore not be justified by appealing to climate protection or positive innovation effects.

CORE TOPICS

RESEARCH AND INNOVATION IN UNIVERSITY MEDICINE B 1

The importance of medical research as a source of innovation continues to grow. What is more, the development of healthcare services in Germany largely depends on medical research. Therefore, research and innovation policies need to place special emphasis on this area. Against this background, the Expert Commission recommends the following:

- Decisions on the establishment and institutional design of additional German Centres for Health Research (DZG) should only be made after the existing centres have been evaluated.
- The bearing of the university hospitals' systemic additional expenses should be balanced out. As these expenses can be partially allocated to patient care and partially to research and training, it is disproportionate to burden solely the health insurance companies.
- The interconnection of basic research and clinical research needs to be advanced further. Geographic concentration of basic research, clinical research and healthcare services should be promoted. Other stakeholders from the health sector should also be included, such as non-university research institutions and private enterprises.
- Research funding allocated to university medicine should be concentrated even further on those locations in Germany that are particularly strong in performance.
- The Coordinating Centres for Clinical Trials (KKS) and the Clinical Study Centres should be developed according to needs. These facilities should not enter into price competition with international institutions, but rather secure a high quality of clinical studies.
- The locations for university medicine should jointly phrase a code of conduct in order to avoid a conflict of interest when cooperating with businesses. Cooperation projects should be communicated as transparently as possible.
- The Federal and *Länder* governments should develop an action plan for the utilisation of large, complex amounts of data in medical research. Such an action plan should be integrated into the Digital Agenda scheduled by the Federal Government.

- Tertiary education students with an interest in research must be given the chance to specialise in research topics at an early stage. MD/PhD degree programmes should be expanded further.
- Physicians engaged in research should be provided with additional rotation positions and fixed time frames for research. Research capacities should no longer be employed for compensating bottlenecks in healthcare services.
- Young physicians with an interest in research should be provided with leeway for independent research. This can be achieved by expanding support and grant programmes.
- Remuneration of physicians engaged in research should be brought more into line with the level of remuneration received by physicians engaged in healthcare activities. The current pay gap reduces the attractiveness of careers in medical research at universities.

B 2 INTERNATIONAL MOBILITY OF SCIENTISTS AND INVENTORS AND ITS IMPACT ON INNOVATION

Overall, Germany has a rather poor balance as regards the international mobility of scientists and inventors. Too few of the best researchers stay in Germany or return to Germany, respectively. With regard to inventors – as measured by patent holders – Germany has a moderate emigration rate and a somewhat larger immigration rate. A particular problem is that the international mobility of inventors reinforces the existing R&D specialisation profile of Germany, i.e. it strengthens the strong fields and weakens the weak fields, such as ICT. The Expert Commission thus recommends the following:

- For attracting top scientists, the excellence of the national research system is decisive. Thus, to increase the competitiveness of the top segment of the German research system, a very good basic funding and excellent opportunities for project financing must be guaranteed. At the same time, research institutions in the top segment need more autonomy to be able to experiment with new staffing or budgetary structures.
- Germany should increase its efforts to attract international talent to Germany and to keep the best researchers in the country. In particular, this applies to the best international young researchers in the doctoral or post-doctoral phase.
- To facilitate the employment of foreign graduate students within the framework of the existing tariff structure, the minimum income threshold that has to be met to be eligible for a residence permit in accordance with § 20 of the Residence Act (AufenthG) should be reduced.
- R&I policymakers and research institutions should aim at attracting top German researchers and inventors working abroad to return to Germany. Additional opportunities should be created to use “pooled appointments”, particularly in strategically important research areas and future core fields.
- Existing returnee programmes for German researchers abroad should be evaluated and should be focussed more on attracting the best researchers to return.
- In addition to fostering excellent research conditions, individual conditions for international mobility of foreign researchers should be improved. In this context, “dual career” issues are increasingly important and should be addressed in the context of visa regulations and when recruiting top foreign talent. Last but not least, the compatibility of European social security systems for researchers and inventors should be improved.

STATUS AND DEVELOPMENT PROSPECTS OF ICT IN GERMANY B 3

Information and communication technology (ICT) plays a pivotal role in the innovation system. As well as its pronounced research intensity, this sector is also characterised by a strong innovation dynamic. Due to its close links with other key areas of industry, ICT is particularly important for Germany's national economy. Therefore, the highest priority must be given to the future development of ICT and its economic and societal benefits. Against this background, the Expert Commission recommends the following:

- In the context of developing the Digital Agenda, the public sector should focus on specific fields of ICT application that are closely related to both the Federal Government's requirement areas as specified in the High-Tech Strategy, and the EU Framework Programme Horizon 2020. These fields of application include intelligent grids in the areas of mobility, healthcare services, energy and e-government, but also the digitalisation of production systems and value chains.
- Innovations in the field of ICT are primarily advanced through business start-ups and international growth strategies of young businesses. New enterprises and international growth should be promoted by means of suitable instruments for innovation and growth financing. This will ensure that, in future, strong German companies will be represented on the international ICT growth markets.
- To an increasing extent, business success in ICT is dependent on system standards and standard-essential patents. German companies and research institutions should exert influence on important international standards. In order to achieve this, the strategic monitoring of standards and active, coordinated participation in important international standardisation procedures are prerequisites.
- The Federal Government should commit to the creation of a unified single European regulatory framework for cloud computing without restricting the flexibility of European companies.
- A systematic evaluation should be conducted to assess whether EU and Federal Government funding resources in the field of ICT actually improve the competitive position of the ICT sector on a sustainable basis.
- Research-intensive SMEs in particular would benefit from R&D tax credits. As these businesses play a key role in ICT, the introduction of tax credits is considered essential.

THE ROLE OF WOMEN IN THE INNOVATION PROCESS B 4

Women are underrepresented in the German innovation system. Compared with men, women are less often enrolled in STEM (Science, Technology, Engineering, and Mathematics) degree courses and are less active in the field of research and development. This imbalance is particularly pronounced at executive levels of industry and research. Considerable innovation potential is thus squandered; innovation potential that Germany in particular depends on as an innovation-based country. Especially in light of the shortages of skilled labour, Germany can no longer afford to underexploit the potential of well-educated women. What is more, greater participation of women in the innovation system would lead to greater diversity in research and management teams, thereby increasing the innovative capacity of Germany as a location.

Against this background, the Expert Commission calls for action in the following areas:

– Women's and girls' interest in and enthusiasm for natural sciences should be fostered to a greater extent than has been the case in the past. In this regard, it is mandatory for the public sector to provide sufficient resources for high-quality teaching in STEM subjects.
– To facilitate the combination of working and family life, the expansion of childcare facilities, and day schools in particular, should be advanced swiftly. Tax regulations (e.g. *Ehegattensplitting*) or childcare benefit regulations that provide incentives for well-trained women to exit their working life must be eliminated.
– As part of its coalition agreement, the Federal Government agreed on introducing a gender quota of 30 percent for non-executive boards of fully co-determined, listed business enterprises. The Expert Commission welcomes this initiative. However, to ensure that the quota and target agreements are met, it is crucial to establish clearly defined sanctions in the case of failure to achieve these goals.
– The proportion of women in executive roles should also be increased in the public administration sector.
– In addition to increasing the representation of women on non-executive boards, the representation of women on executive boards must also be addressed. The Corporate Governance Code should be employed to effectively increase the proportion of women on executive boards, as means of legal implementation are lacking in this area.

CURRENT DEVELOPMENTS AND CHALLENGES

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A CURRENT DEVELOPMENTS AND CHALLENGES

A 1 FURTHER DEVELOPING THE REFORM INITIATIVES

The necessity of supporting the science system beyond the expiry of the reform initiatives

The Higher Education Pact, the Excellence Initiative and the Pact for Research and Innovation have considerably improved Germany's performance as a research and innovation location. As these reform initiatives are due to expire within the next few years, the course has to be set for developing the science system further now that the new legislative term has begun. Prior to the 2013 federal parliamentary elections, the Alliance of Science Organisations in Germany, the German Research Foundation (DFG), Germany's four large non-university research organisations, as well as the German Rectors' Conference and the German Council of Science and Humanities all drafted their proposals on further supporting the science system.[1]

Reliable financing for tertiary education institutions is essential

A highly developed academic landscape is the basis for a competitive research and innovation system. Therefore, Germany will have to further strengthen the financing basis of tertiary education institutions over the coming years. However, this should not be accomplished by once again raising the proportion of third-party funds. Instead, the financing basis should be strengthened by increasing basic funds in the long term.[2] The governing parties have announced that they will provide tertiary education institutions with additional basic funding. Yet, direct financing by the Federal Government can only be realised by amending the German constitution. However, there is no mention of this in the coalition agreement,[3] it merely states that the financial burden of the *Länder* governments shall be eased in order to support the *Länder* governments in meeting e.g. the challenges of financing tertiary education institutions.[4] It remains unclear how the Federal Government will ensure that resources are utilised for this specific purpose.

When implementing projects financed by third parties, tertiary education institutions have to bear the overhead costs in addition to the direct project costs. These overhead costs include e.g. administrative services or costs arising from the use of facilities. In 2007, the DFG introduced a programme allowance amounting to 20 percent of the direct costs of a project,[5] and since 2011, the Federal Ministry of Education and Research (BMBF) also provides for a project allowance of currently 20 percent. Yet these allowances do not suffice to fully cover the actual overhead costs of a project.[6] Therefore, tertiary education institutions are forced to employ basic funds in order to cover the overhead costs. Hence, the financial situation of tertiary education institutions could also be improved by taking grater account of overhead costs when financing projects. While this does not represent a means of direct institutional funding, a stronger emphasis on overhead costs would certainly help save basic funds.

The Higher Education Pact 2020 aims to secure sufficient study opportunities,[7] while the Quality Pact for Teaching is designed to improve conditions for studying and the quality of teaching.[8] According to the coalition agreement, the Higher Education Pact 2020 shall be continued, and tertiary education institutions shall be rewarded to a greater extent for good teaching and quality assured successful final degrees.[9] The Expert Commission welcomes the stronger focus on teaching quality that accompanies this. That said, options for improving the quality of teaching are limited, unless the current capacity regulations (KapVO) are amended. Based on curricular standard values (CNW), the capacity regulations determine the teaching effort required for the training of one student, which is measured in teaching load hours. This means that the student/teacher ratio (i.e. the ratio of students per fulltime professor) can only be improved if the number of teaching load hours is increased.

Vertical and horizontal differentiation in the higher education sector should be enhanced

The governing parties have agreed to continue those funding lines from the Excellence Initiative that have proven to be particularly successful and to transfer these into new funding formats.[10] The Expert Commission believes that all three funding lines have initiated important developments that need to be pursued further. The international visibility of selected tertiary education institutions has been increased by introducing a "seal of excellence". Furthermore, thematic focal areas have been initiated through the promotion of graduate schools and clusters of excellence. The Excellence Initiative has thus enhanced vertical and horizontal differentiation in the German higher education sector.[11] Both developments mark important steps towards a higher education system that can compete internationally. The coalition agreement does not include any statement as regards the promotion of a selected number of high-performing universities. The Expert Commission reiterates that Germany needs strong research universities that are able to compete in international rankings. Top researchers can only be attracted if German universities are highly visible at international level (cf. Chapter B 2). This, however, is a fact that is largely ignored in the current political debates.[12]

The need to optimise conditions for non-university research organisations

The governing parties have agreed to continue the support of non-university research organisations by ensuring a dependable increase in funding. According to the coalition agreement, additional funds for Germany's non-university research organisations shall be provided solely by the Federal Government.[13] However, the precise level of funding has not been determined as of yet. The Expert Commission would like to point out that the performance of non-university research institutions can only be enhanced further if an increase in funding is granted not only in nominal, but also in real terms.

The Expert Commission is in favour of further strengthening cooperation between non-university research organisations and tertiary education institutions. However, collaborations should be motivated by scientific reasons rather than financial reasons. By standardising the federal-state financing key for all non-university research organisations, collaboration between these organisations and *Länder*-funded universities could be facilitated.[14]

The Helmholtz Association (HGF) has suggested broadening its mandate.[15] According to the HGF's proposal, institutional funding should be integrated more closely with project funding so as to facilitate a cross-institutional, programmatic funding practice. Yet, in the view of the Expert Commission, non-university research organisations should not be entrusted with the role of project promoter, as this may lead to serious conflicts of interest.

Recommendations

In the coming months, a detailed, coherent package of measures will have to be developed to further support tertiary education institutions and non-university research organisations beyond the expiry of the Higher Education Pact, the Excellence Initiative and the Pact for Research and Innovation. Despite financial constraints, the success of these pacts will have to be perpetuated, and the further development of the German science system will have to be continued to avoid falling behind in international competition. Relevant support measures should be developed within the framework of the goal of achieving an R&D intensity that is well above 3 percent by 2020.

– Strengthening basic funding of tertiary education institutions is more important than creating new, small-scale policy instruments. In this context, the Expert Commission reiterates the urgent need to amend Article 91b of the German constitution. This would re-enable the Federal Government to support tertiary education institutions at an institutional level and ensure that the higher education sector receives additional funding.[16] The respective amendment of the German constitution should not be made dependent on lifting the cooperation ban in the area of schools.

– Teaching commitments of professors at German tertiary education institutions are not internationally competitive. In the course of the expected decline in student numbers, teaching commitments should be reduced and should be made more flexible. At the same time, the curricular standard values should be redesigned to achieve student/teacher ratios that are still internationally competitive from a student's perspective.
– The DFG programme allowance and the BMBF project allowance should be gradually increased and, wherever necessary, differentiated according to academic disciplines. In the medium term, any projects funded by the public sector should be granted full-cost funding.
– Tertiary education institutions with a particularly strong performance (i.e. elite universities) require special support in order to ensure high visibility of the German research system. The selection of institutions to be supported should be conducted as part of a competition. Here, not only the current academic performance, but also the institutions' development concepts should be assessed. The funding period should clearly exceed five years, and the funding scheme should also provide for institutions to ascend or descend in ranking.
– The Expert Commission is in favour of integrating the graduate schools and clusters of excellence into the DFG's portfolio – a measure that has also been suggested by the German Council of Science and Humanities and the Alliance of Science Organisations in Germany.
– The Federal and *Länder* governments should support non-university research organisations with a uniform financing key of approximately 70:30.[17] The Expert Commission reiterates that non-university research organisations will only be able to further enhance their performance if an increase in funding is granted not only in nominal, but also in real terms.
– A conflation of the implementation of research and the funding of research should be avoided.

A 2 PROMOTING INNOVATION MORE EFFICIENTLY THROUGH THE EVALUATION OF POLICY MEASURES

Political action serves to achieve specific goals. In addition to ensuring the effectiveness of a policy measure, it is also important to ensure the cost efficiency of allocated resources. Evaluations of individual policy measures can help determine how a measure must be designed in order to achieve the desired effect with a reasonable use of resources.

This also is of central importance in the area of research and innovation policy. The key is to know what type of funding is economically sensible. Not only the type of support, but also the potential recipient and the amount of support are decisive for the success of a measure. By means of a valid evaluation of funding measures, it can be established which of the allocated resources are most effective, how big the impact of funding is, and how measures can be improved further. Evaluations thus facilitate the competition of ideas in the search for the best long-term results in promoting innovation. If an evaluation is integrated into the project planning from the very start, additional costs arising from the evaluation will be relatively modest. In contrast, if evaluations are not employed, this can lead to efficiency losses and thus significantly higher costs. This is especially true if, as a result, other innovative ideas do not receive sufficient financial support.

To date, the practice of evaluation in Germany has shown a mixed picture: the need for evaluations has been recognised by various stakeholders, and many policy measures are already being evaluated. Yet, the scientific quality of evaluations is an issue that remains to be addressed. In many ministries, support measures are mostly evaluated prior to the allocation of funds, i.e. ex-ante. However, this does not suffice for determining the actual achieved efficiency of support measures. Therefore, accompanying evaluations as well as ex-post evaluations are of central importance. Based on valid scientific methods, such evaluations determine the extent to which a measure has been effective, thereby providing a solid basis for policy decisions on the continuation of or necessary adjustments to policy measures.

Several attempts have been made to anchor the topic of evaluation in research and innovation funding. In mid-2011, the Federal Ministry for Economic Affairs and Energy set up a specialist staff unit *(Aufbaustab Födercontrolling/Evaluation)* responsible for assessing and controlling support measures and the evaluation thereof. The ministry's subject-specific divisions are required to involve the staff unit in the early stages of tendering and awarding evaluations, as well as in the reporting process. In the Federal Ministry of Education and Research (BMBF), the ministry's subject-specific divisions are currently in charge of evaluating the effects of support measures. In addition, the BMBF is planning to establish an additional expert unit, which shall be responsible for fundamental and strategic issues relating to evaluations.

Furthermore, on 23 January 2013, the State Secretary Committee decided that in future, any proposed legislation shall be evaluated ex-post if the ex-ante expected annual compliance costs exceed one million euro. Such ex-post evaluations shall be conducted three to five years after the launch of a measure. Yet, the committee does not elaborate on the methodological standards to be applied.[18]

Germany's evaluation practice is most developed in the field of labour market policy, which is also the case in other countries.[19] The evaluation practice in this field offers impressive evidence of the importance of impact analyses for decision-making in economic policy. Based on evaluations, job creation measures that had been introduced in the 1990s were abolished in 2012 as their effectiveness could not be demonstrated. In the course of advancing the evaluation practice further, scientists have also been granted access to research data on major labour market programmes. Above all, this has ensured that competing studies could be produced on the same research issues. This has led to improvements in the overall quality of studies. The success of this change in practice illustrates the enormous potential of evidence-based economic policy. Other policy areas, however, are still far from employing such evaluation practices, in spite of promising approaches. A view of the bigger picture shows that Germany could hugely benefit from experience gained in other countries and other policy areas.

International best practice examples

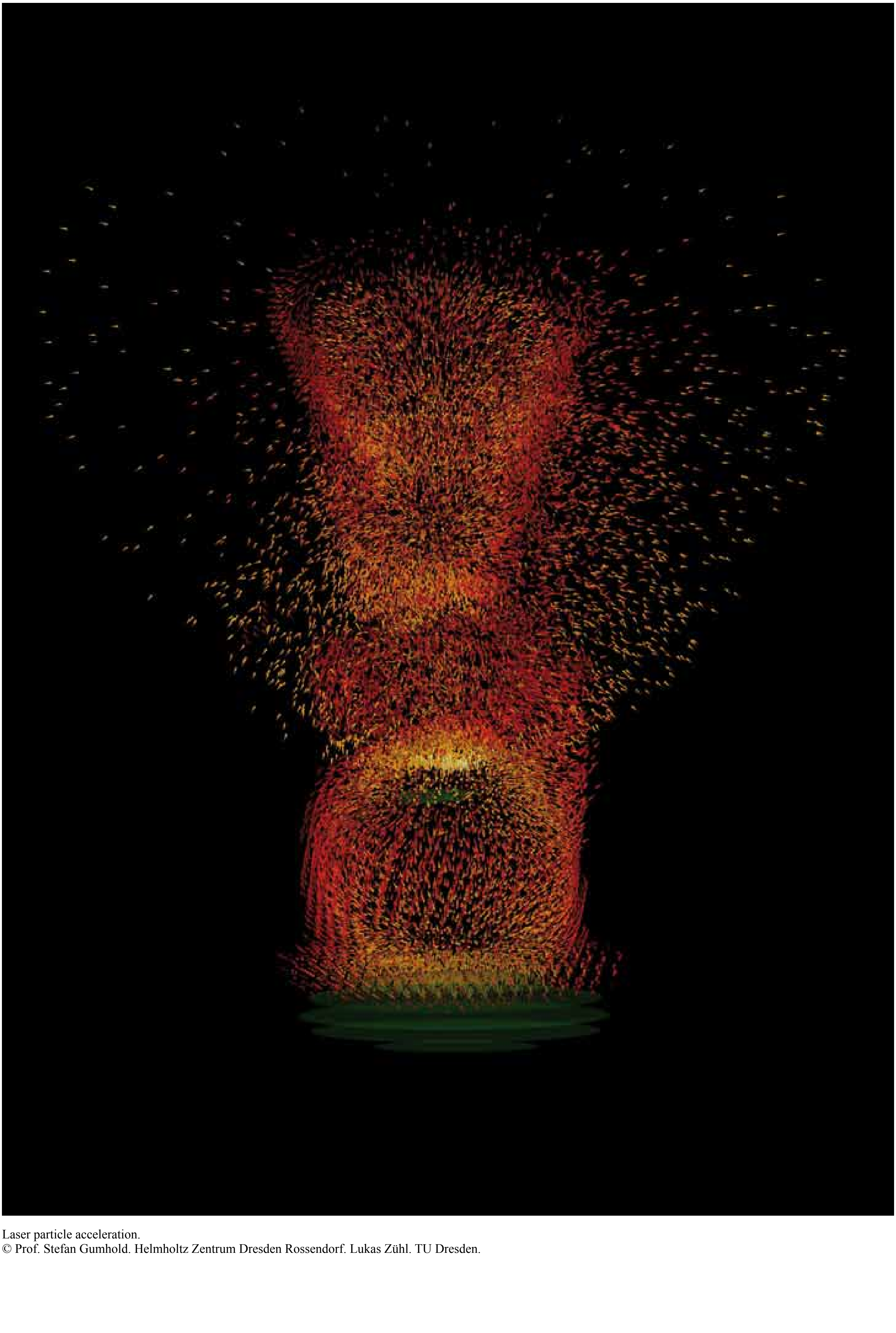
In a number of policy areas, the United States have a long tradition of evaluating government programmes based on scientific procedures. Relevant examples include the Tennessee STAR experiment,[20] which focussed on measuring the effect of class size on the learning outcomes of students, as well as the RAND experiment[21] on the effects of health insurance.[22]

Following the implementation of the American Recovery and Reinvestment Act of 2009, the United States have also been placing greater emphasis on employing impact analyses in the field of economic policy measures. The Office of Management and Budget (OMB) plays a central role in putting these objectives into practice.[23] According to the OMB guidelines, evaluations shall constitute an integral part when allocating resources. The objective is to award the bulk of funding to support measures with proven effectiveness. Another portion of funding is earmarked for programmes that are endorsed by positive initial evaluations, but have not been conclusively assessed. Resources are allocated to these programmes under the condition that further evaluations will be implemented. The remaining portion of funds will then be invested in innovative and potentially successful programmes that are yet to be evaluated.[24]

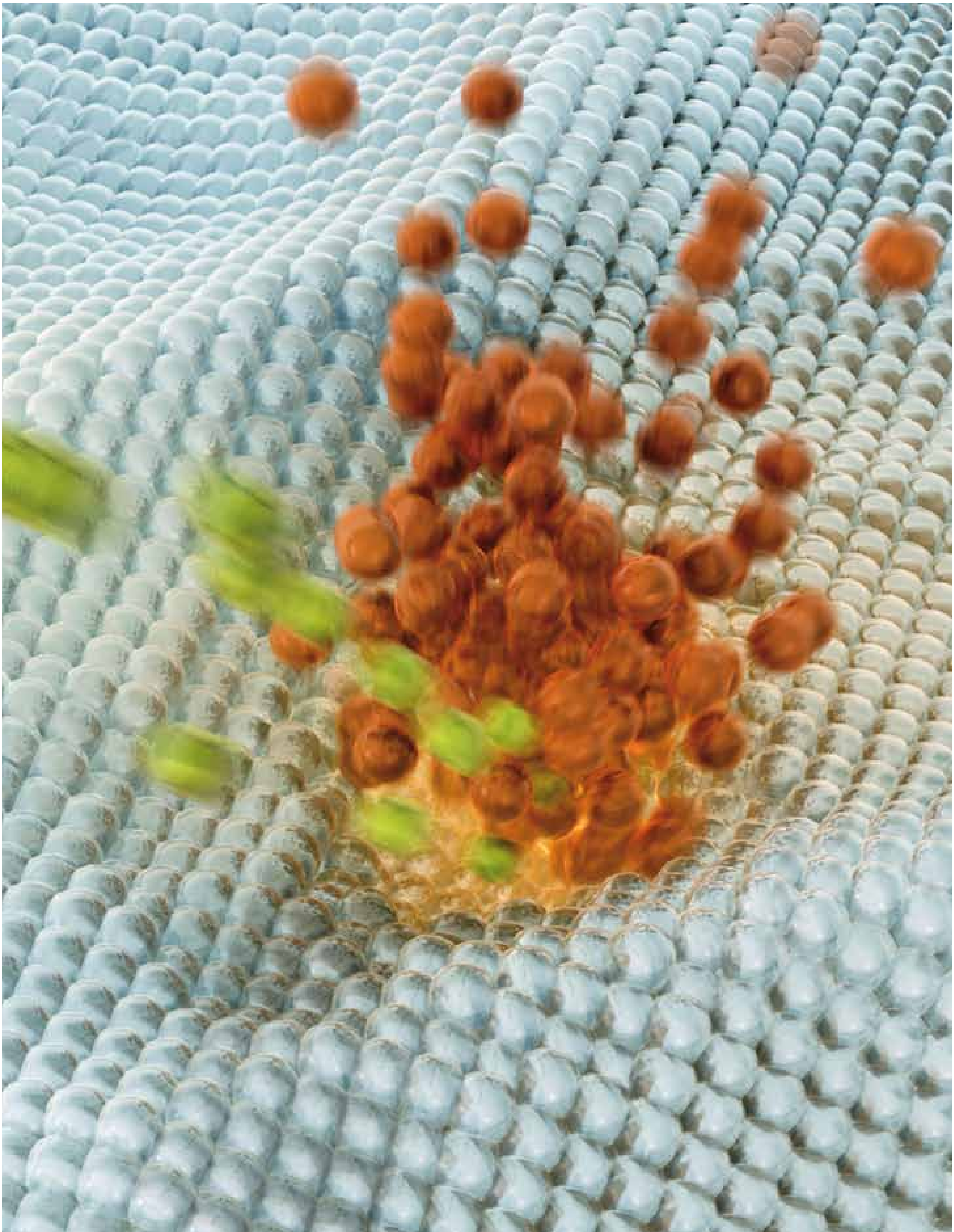
To date, policy evaluations have largely focussed on social programmes. To solve the United States' most pressing social problems, promising concepts are being identified, and pilot projects are being implemented and post-evaluated. If an evaluation proves positive, measures are widely implemented.[25] But even after implementation, measures are continuously monitored with regard to their effectiveness. In this process, it is important to regard impact analyses as an integral part of the decision-making process from the outset of a project. This will guarantee comprehensive evaluation opportunities, allowing stakeholders to factor in data requirements during a measure's planning phase. Furthermore, it will also ensure the cost-effectiveness of an evaluation, since the additional expenses incurred by evaluations tend to be very modest in relation to a measure's overall costs when planned in advance.

The institutionalisation of evaluations plays a key role in achieving the goal of an evidence-based allocation of resources. In the United States, specific institutions have been established for this purpose. In 2009, the Department of Labor set up its own Chief Evaluation Office (CEO), which serves as the central office for the evaluation of all labour market measures applied by the ministry. The CEO does not set its own goals, but rather aims to evaluate specific measures or arrange for their evaluation. 0.5 percent of each project's budget is allocated to the evaluation team (up to 1 percent from 2013).[26] The CEO's total budget for the planning and coordination of evaluations currently amounts to approximately 40 million US dollars. The impact analyses themselves are carried out by specialised institutes, and the main focus is placed on the efficiency and effectiveness of programmes. The CEO is responsible for identifying useful measures, for improving existing measures and uncovering new potential. For the purpose of quality assurance, the CEO also provides a publicly accessible data set of each of the CEO's quantitative evaluations, thereby allowing to reproduce the main findings of evaluations. Furthermore, all evaluations commissioned by the CEO are peer-reviewed. These elements of quality assurance are of great importance.

But also in other policy areas, the evaluation of measures is an integral part of political practice, education policy being a prime example. Here, the United States have set milestones in educational research, especially through the use of randomised experiments.[27] Since many of the programmes are launched at a local level, it is particularly important to coordinate and disseminate information efficiently. In the area of education, this is primarily done through the website WhatWorksClearinghouse (WWC). The WWC gathers and assesses studies on various educational programmes (cf. Box 1), which are then presented on a central website. For each measure, the WWC website provides a comprehensible overview of the contents, purpose and effects of a measure. To date, slightly less than 40 percent of the total of studies assessed have been classified as largely compliant with standards, and only about 20 percent have been classified as fully compliant with standards. From among those 328 (methodologically valid) results



Laser particle acceleration.



Ion beam.

BOX 01

How to recognise good impact analyses

To assess the validity of an evaluation's results, it is first crucial that the study is implemented transparently in every respect. In particular, this includes a clear presentation of the implementation of the evaluation. As part of an experimental study, it must be documented that groups have been assigned prior to the experiment, how the grouping was conducted and whether the random assignment led to groups that are actually comparable. This is to prevent results that are based on group differences from being attributed to the support measure itself. Studies designed to produce valid results should have large sample sizes so as to rule out random effects. Furthermore, to isolate the cause of an observed change, evaluations should be conducted in an environment that is as normal as possible. Ideally, the evaluation of a measure should be conducted in more than one location to prevent the particular circumstances of a region from producing spurious results. Prior to an analysis, it should be established based on which criteria results are to be determined. These results should be presented in a clear-cut way to allow the assessment of the measure's effectiveness. If the desired evaluation methods cannot be implemented, or if the random assignment has proven to lead to incomparable groups, the most important factors influencing the evaluation's results should be controlled for. The results of studies that merely show a before-and-after comparison or those that do not sufficiently control for influencing factors cannot be regarded as valid results. In such cases, it cannot be ensured that results are actually a consequence of the support measure and are not due to other, unobserved factors. However, whether a support measure in whole can be regarded as scientifically well-founded does not only depend on the quality of the studies, but also on the quantity of evidence. Therefore, to produce reliable results, a high-quality study should be replicated in at least one additional, representative environment.

from 209 measures, only about half of the results have been positive or potentially positive.[28] A comparable project is currently being conducted in the area of combating crime. The US Department of Justice has launched the website CrimeSolutions.gov, a site that aims to present impact analyses on policy measures, such as measures to promote the reintegration of youths that have been convicted of criminal offences. What both websites have in common is that they do not only include domestic studies in their databases, but also take into account studies from other countries. Thus, in terms of transparent evaluations of policy measures, the United States are very well positioned.

Some of the European countries also present findings systematically. For example, the University of Aarhus operates the Danish Clearinghouse for Educational Research, which serves a similar purpose as the aforementioned websites.[29]

The Canadian Social Research and Demonstration Corporation (SRDC), founded in 1991, is another example of good practice in North America. The SRDC evaluates policy measures for a number of public authorities. The SRDC specialises in test projects that are evaluated with a number of different methods, depending on the project. The SRDC uses both quantitative and qualitative methods. From the outset, the SRDC makes use of randomised experiments to facilitate well-founded evaluations.

In 2010, Great Britain established its Behavioural Insights Team (BIT). This facility aims to identify ways of making the government work in a more efficient and target-oriented way. In cooperation with authorities, the BIT examines e.g. strategies for improving the services of employment agencies, and strategies for making traffic offenders pay their outstanding fines.[30] At the BIT, the collection of data required for a well-founded impact analysis is integrated into the planning phase of the project to ensure a cost-effective evaluation. Results are then managed by centralised evaluation teams, which combine the findings of various projects. Following a trial period, the BIT's funding was continued and the team was expanded due to its great success. The BIT is now to become partly privatised.[31]

Since 1999, Switzerland has analysed the effectiveness of public policies as part of its constitution. Article 170 of the Swiss Constitution states: "The Federal Assembly shall ensure that federal measures are evaluated with regard to their effectiveness." The Swiss Agency for Development and Cooperation, Switzerland's national development aid organisation, has derived its own evaluation standards from this constitutional mandate. According to these standards, 0.6 to 0.8 percent of project funds must be allocated to the impact analysis budget.

In the Netherlands, the institutionalisation of the evaluation process was introduced shortly after the Second World War. There, the Central Planning Bureau (CPB) is in charge of evaluating economic policy measures. Above all, this includes the ex-ante cost-benefit analysis of policy proposals. In recent years, however, the CPB has also been initiating the use of scientific ex-post evaluations, while making frequent use of both natural[32] and actual experiments. The issuing of innovation vouchers to small and medium-sized enterprises (SMEs) may serve as an example of actual experiments.[33] With the help of these vouchers, businesses were able to award small projects to research institutions. The aim of the experiment was to determine whether vouchers are an effective means of promoting the innovation activities of SMEs, and whether vouchers can strengthen relations between SMEs and scientific institutions. The efficiency of the measure could be shown easily and convincingly as a limited number of vouchers was randomly assigned to candidates in an oversubscribed lottery.[34] It is planned to increase the use of scientifically founded evaluation measures in the future.[35]

These examples demonstrate that the implementation of well-founded evaluations is both possible and desirable. Tests conducted in other countries have been extended without exception and often play an important role in political decision-making. Germany could also benefit from such developments.

Challenges in the evaluation process

Evaluations provide important information on the effectiveness of a measure in the observed context. Yet, when it comes to provisional measures that have been introduced for test purposes, it is important to assess to what extent their effects can be generalised once the measure is introduced on a broader basis. In particular, it is essential to examine whether the results from a specific testing environment are transferable to other parts of the population. Another important point in the evaluation process is that long-term or downstream effects cannot be conclusively assessed if the evaluation period is too short.[36]

The implementation of evaluations must also be designed in a way that allows for a relevant selection of quantitative and qualitative criteria that precisely suit the respective measures.[37]

Due to major advances in methodology, it is possible to draw valid conclusions even in cases where experimental evaluations are not feasible.[38] A suitable design of the implementation of the measure can then facilitate well-founded results that come close to experimental standards. Qualitative evaluations can also contribute greatly to the evaluation of economic policy measures. In any case, the introduction of scientifically sound evaluations represents a significant advance towards an evidence-based innovation policy.

Recommendations

The Expert Commission recommends the systematic use of scientifically well-founded impact analyses in research and innovation policy measures. Already in the planning of measures, concrete objectives should be set and, whenever possible, suitable indicators should be defined that will allow for a subsequent assessment of whether objectives have been achieved. It is essential to consider evaluations already in the project planning phase and to immediately record the data required.

Evaluations provide the basis for informed political decisions. As a key prerequisite, evaluations have to be conducted without prejudging the outcome, and both positive and negative results have to be appreciated as knowledge advancements. Evaluations should not be regarded as a potential career threat by those responsible for a measure. To keep those in charge from refusing impact analyses on these grounds, the success criterion of an evaluation should be knowledge advancement and the improvement recommendations derived from it rather than a positive assessment of a measure. In particular, political stakeholders should create the opportunity to reallocate budgets and to further develop measures instead of completely terminating them.

The Expert Commission recommends the establishment of centralised evaluation offices at ministerial level to be in charge of implementing and assessing scientifically valid evaluations. First attempts – such as the establishment of a staff unit for assessing and controlling support measures at the Federal Ministry for Economic Affairs and Energy – should be systematically advanced. The Expert Commission particularly recommends the creation of a Chief Evaluation Office following that of the US Department of Labor in all those federal ministries that have major budgets for the promotion of research and innovation. These centralised bodies should operate independently and should define standards for evaluation. Furthermore, the Expert Commission recommends introducing research data centres in all of the ministries concerned. These centres should have the purpose of collecting and processing data of all projects that aim to promote research and innovation. Data should be made available to researchers to be used for evaluation purposes. To allow the commissioning of evaluations by the ministries, the centralised evaluation bodies should receive 0.5 percent of the programme budget of all ongoing projects. These funds shall be allocated to evaluations and their methodological advancement. When putting evaluations up for tender, special attention should be attached to the methodological expertise of the tendering parties. The Expert Commission recommends fostering quality-based competition and focussing on providing ongoing incentives for new, qualified tenderers. This can be achieved through suitable tendering procedures and by considering international bidding consortia.

To improve the transparency of evidence-based support measures, the Expert Commission recommends the launch of central websites by the respective ministries. This should be done by using the above best practice examples and possibly in cooperation with the respective institutions. These websites should collate all results of evaluations in the area of research and innovation that aim to increase the effectiveness of individual measures. The collated results should be assessed according to their methodological quality.

To ensure that evaluation standards are implemented in the ministries, the Expert Commission recommends the provision of systematic training for ministerial staff and the recruitment of new staff with strong methodological skills. An ongoing exchange between ministerial staff and external empirical researchers in the form of further training and workshops would further support the development of skills.

The Expert Commission finally recommends promoting the implementation of these efforts also at a European level. By launching suitable initiatives, the Federal Government could become a pioneer in the field of evidence-based innovation policy.

A 3 THE RELEVANCE OF TERTIARY EDUCATION AND VOCATIONAL EDUCATION AND TRAINING FOR INNOVATION

Strengthening the innovation system by combining vocational and academic qualifications

The German production and innovation model, particularly in the industrial sector, is based on a specific combination of highly qualified university graduates – mostly from natural sciences and engineering – and highly skilled workers from the dual vocational education system.[39] This structure prevents a narrowing on academic knowledge, a phenomenon that can be observed in many countries.[40] Instead, the German system builds on a combination of different, high-quality sources of knowledge. These sources of knowledge include occupational skills and process-oriented competencies, application-oriented analytical skills as well as abstract theoretical and analytical expertise. The success of the German model largely results from close links between R&D and production accompanied by the spatial proximity of highly skilled workers from diverse backgrounds – ranging from development engineers to skilled workers from various disciplines.[41] High-quality innovations arise from the fact that employees with different qualifications have a common professional language, and that a regular exchange of experience is not only facilitated, but also promoted.[42]

The combination of tertiary education graduates and highly skilled workers proves to be most effective whenever the exchange of knowledge among different skill types is supported by complementary human resource or organisational management practices. These practices include e.g. teamwork, job rotation, broad spans of control, and the delegation of decision-making.[43] In this context, the participation of companies in training apprentices in the dual system shows a positive effect on innovation: training companies are required to keep their training in line with advanced technological standards to meet the requirements of externally developed training curricula which are updated regularly. This ensures a continuous supply of skilled workers with state-of-the-art qualifications.[44] By participating in apprentice training, companies also improve their chances of recruiting highly skilled workers from the external labour market.[45] A solid pool of skilled workers graduating from dual training programmes and thereby having a specific combination of the most recent practical and analytical skills also contributes to a more effective dissemination of process innovations. This has been demonstrated e.g. in a comparative study on the application of CNC (computer numerical control) in German as compared to foreign companies.[46]

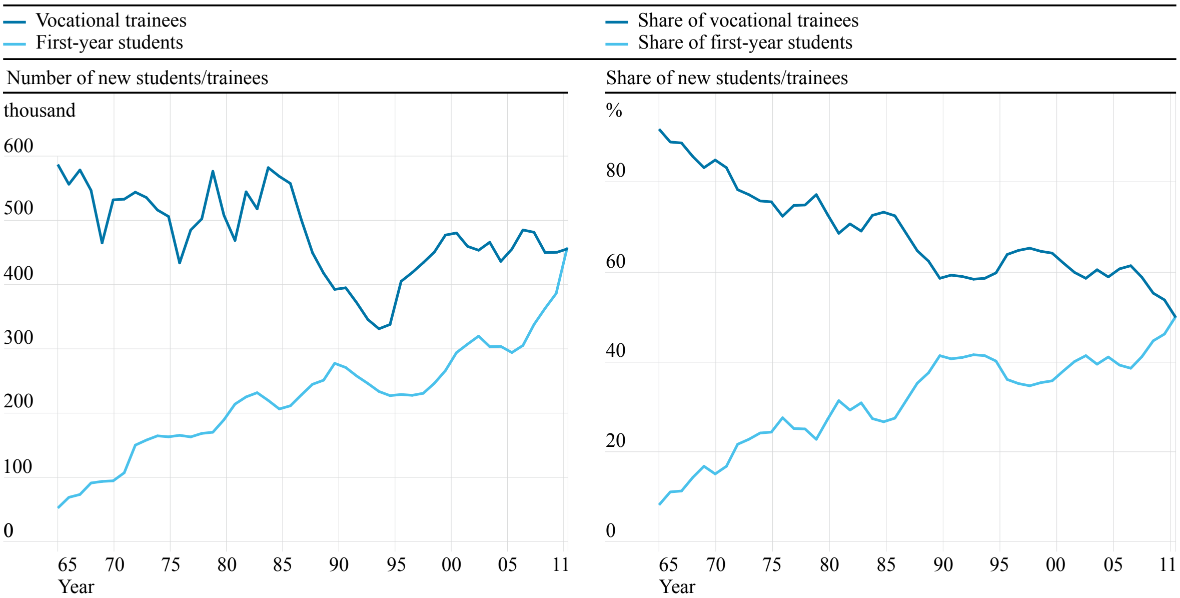
Another important component of the German innovation model is its industrial ecosystem, which is characterised by its variety of relevant resources. The industrial ecosystem in Germany includes suppliers cooperating in development, a wide range of public research and financing institutions, and a functioning dual education system that provides the necessary institutional framework. This system, which cannot be found in Anglo-Saxon countries in particular, provides a basis for German companies to develop their innovation activities.[47] When compared with the United States' system,[48] one of the strengths of Germany's dual system of vocational education and training lies in the fact that a high number of small and medium-sized enterprises are involved in the training of skilled workers within the dual system.[49] In Germany, the interplay of different-sized enterprises on the labour market and the coordinating efforts made by public institutions contribute to the emergence of a comprehensive network that ensures a sufficient supply of skilled workers who meet the most recent qualification requirements.

For example, the early developments in the field of information and communication technologies (ICT) demonstrate that the German vocational education system is able to master the balancing act between standardised training regulations and the need to adapt to changing skills requirements resulting from technological progress. In the late 1990s it was still being discussed if and how the vocational education system would be able to provide skilled workers in future-oriented industries such as ICT.[50] In the meantime, the actual development of apprenticeship training in IT occupations has demonstrated that the dual

First-year tertiary students and first-year vocational trainees of the dual system in the former territory of the Federal Republic of Germany 1965 to 2011

FIG 01

DATA DOWNLOAD



Source: own depiction. Data on vocational schools up to 1990 according to Lundgreen (2008), data from 1991 according to school records *(StBA, Fachserie11 Reihe 2)*; first-year students according to university records *(StBA, Fachserie 11 Reihe 4.1)*, calculations by SOFI.
In: Baethge et al. (2014).

vocational education system has done very well even in coping with the dramatic changes in this specific industry: a total of 160,000 individuals successfully completed their apprenticeship training in IT occupations between 1997, when IT occupations were first introduced in the dual system, and 2012. IT occupations may thus serve as a prime example for the vocational education system's ability to adapt to technological progress.[51] Moreover, even start-ups and young enterprises got involved in dual vocational training relatively quickly resulting in the dissemination of the new job profiles in ICT.[52]

Potential threats to the German innovation system posed by trends in the education and employment system

However, Germany's education system is subjected to major changes that jeopardise the advantages of the German innovation system as described above: over the past decades, the ratio between vocational and general tertiary education has shifted dramatically. While in the mid-1960s, 92 percent of school-leavers entered into vocational training and only 8 percent enrolled in university education, in 2011 – for the first time in German history – the share of newly enrolled university students (50.1 percent) and the share of newly enrolled participants in dual training (49.9 percent, cf. Figure 1) were almost equal.[53]

Today, also fewer dual educated workers advance to an engineering level through further education and training, a phenomenon which was still fairly widespread during the 1990s.[54]

Yet, as long as the absolute number of school-leavers was increasing, the growing proportion of first-year students did not lead to serious problems in the vocational education system because the absolute number of vocational graduates remained relatively stable (cf. Figure 1).[55]

However, this situation will change dramatically when taking into account the foreseeable demographic change and the resulting decline in pupil numbers. If the proportion of participants in vocational education remains at this historical low level and the number of pupils continues to decline, the absolute number of new trainees in the vocational education system will also decline rapidly. While more and more pupils aim for a university entrance qualification *(Abitur),* fewer and fewer pupils consider obtaining a double qualification by entering into vocational training once they have obtained their *Abitur*.[56] It is yet unclear whether the growing number of dual studies *(duale Studiengänge)* simply fills this gap in double qualification by offering university education alongside vocational training, or whether this represents the emergence of a new type of student and academic study.[57]

Yet, it is evident that the classical form of vocational training has been subject to increasing pressure as a result of the aforementioned trends.[58] For almost 20 years now, political stakeholders in national and international educational policy have been focussing on academic pathways.[59] This has led to significant changes in the training preferences of the younger generations and their parents. Here, one of the driving forces has been the OECD's country comparisons "Education at a glance" anchored in an Anglo-Saxon tradition. Over the last decades, these studies set an increase of the student ratio as the major goal for educational policy.[60] This strong focus on academic education is based on the assumption that a university degree would generally offer the best career options, and that academic education could be used on a broader basis in later working life. In contrast, a vocational training course is thought to restrict a candidate's career and labour market options as it supposedly requires candidates to commit to a confined vocational field from the very start. Yet, studies using more advanced methods to examine the labour market outcomes of different types of education demonstrate that such descriptive comparisons clearly fall short and produce incorrect results for returns to education (cf. Box 2). For instance, an advanced study for Switzerland,[61] which takes into account both selection and heterogeneity problems, shows that academic education, when compared to vocational training, leads to significant income gains at the top end of the income distribution, i.e. among the best graduates, these gains disappear in the middle part of the income distribution. They even turn into the negative in the lower part of the distribution. This means that for a large proportion of graduates, dual vocational training generates returns to education that are equally high as, or even higher than, those achieved through academic education.[62]

Recent studies have also shown that occupational mobility, i.e. movements between different businesses

BOX 02

Methodological difficulties in assessing the relative advantages of academic vs. vocational education based on observed differences in income

The widespread assumption that academic education is better than vocational education stems from the observation that many academics generate a good income, tend to have good employment careers and tend to be less affected by unemployment. However, the observed differences in average income between academics and non-academics can by no means be attributed to a causal effect of the type of education alone but may simply reflect differences in the distribution of initial ability. Since academics tend to stem from the upper part of the ability distribution[63] and non-academics, on average, tend to stem from the lower part, this means that their respective incomes will differ considerably for that reason alone. Thus, it is very difficult to assess to what extent current income differences are attributable to said differences in the distribution of ability, and to what extent they are attributable to the causal effect of higher educational levels. It is not possible to observe the income of an academic if he or she had received a non-academic training. Vice versa, it is not possible to observe the income of a non-academic if he or she had chosen an academic career. Yet, this counterfactual observation would be essential for proving the causal effects of academic education.

Besides this selection issue, another problem in measuring educational returns is the fact that the effects of training courses may vary depending on the participant's initial ability. Differences in cognitive skills may serve as an example for illustrating this problem. Thus, it can be assumed that the same academic education will generate stronger effects for individuals with above-average cognitive skills when compared with individuals with below-average cognitive skills. This leads to further distortions in the measured effects. Yet, to date there are virtually no empirical findings available on the causal effects of alternative educational paths for different initial ability levels of candidates.

and occupations, is not confined to individuals with academic education but also applies to those with a background in vocational education.[64] Further studies on Switzerland demonstrate that the highest income levels do not necessarily result from purely academic education. In fact, a combination of educational paths that includes both vocational and academic education can be quite advantageous since combinations of different educational types result in special complementarities of vocational experience and theoretical knowledge.[65] A permeable education system, such as the one that has emerged in recent years in Switzerland, intensifies such complementary effects. In Switzerland, talented graduates from vocational training are provided with good options for advancing their education within the framework of higher vocational education (Tertiary B) or entering into an academic education pathway (Tertiary A).[66] Finally, studies on Germany have shown that, in principle, vocational training is not necessarily a disadvantage when compared to academic education – even during times of structural change. Although skills relating to specific products, processes or technologies tend to be devalued to a higher degree than experience-based or social skills in times of structural change, it seems that neither academic nor vocational education proves to be generally advantageous in this regard.[67]

The main challenges for the coming decades and possible solutions

The decline in pupil numbers due to foreseeable demographic changes, coupled with student-driven financing keys at the general and tertiary education systems plus a general strive for academic education in public opinion and among parents, coupled with low or largely lacking external performance standards in the general education system contribute to an inexorable drift towards general and tertiary education and away from vocational education.

The incentives for all parties involved (parents, children, heads of schools) are pushing in the same direction, towards more and more students entering upper secondary schools and tertiary education institutions. Once started, this process is difficult to bring to a halt, as a continuous decrease in student numbers and reputation reinforces itself and leads ever fewer young people to want to remain in the vocational education system. Over the past decades, a similar process has resulted in a dramatic deline of general secondary schools *(Hauptschulen)* in Germany, which have even been abolished in several of the federal states *(Länder)*.[68]

Given the strengths of the German innovation system described above, Germany's political stakeholders should engage in measures to counteract a similarly strong drift away from dual training. In times of declining pupil numbers, financing keys based on pupil numbers are setting strong incentives for schools to accept greater proportions of students. If a larger share of students enters into upper secondary schools and universities, this can lead to a downward spiral in the performance requirements of these educational institutions, because by lowering their performance standards schools will be able to get a larger share of the shrinking number of pupils (individual schools with high performance standards may instead be exposed to a disproportionate decline in pupil numbers and thus funding).

To ensure that Germany maintains its solid mix of highly skilled workers and graduates from the tertiary education system, a package of different measures and potential solutions are expedient here.

First, it is of central importance to continue investments in maintaining and developing the attractiveness of vocational education. This has to be ensured mainly by a high quality of training and by regularly adapting training regulations to the new challenges of the knowledge society. In addition, the strengths of vocational education need to be communicated more clearly to external target groups – especially to foreign managers and other decision-makers who are not yet familiar with Germany's dual vocational education system. Stakeholders from the relevant bodies involved – i.e. social partners, the Federal Institute for Vocational Education and Training *(Bundesinstitut für Berufsbildung)*, businesses, vocational schools, as well as the Federal and *Länder* governments – are called upon to participate in these efforts.

Issues appearing at the bottom of the ability distribution differ significantly from those appearing at the top. It is therefore important to discuss issues independently and to deal with them separately. The most pressing issues at the bottom of the ability distribution are caused by a lack of educational requirements and initial missed opportunities. Such youths must also be given the chance to prove themselves in real work environments and develop their diverse skills and qualifications from an early stage on. Here, the close relationship between the trainer and the trainee – which in small businesses often comes down to one-to-one coaching – can be a structural advantage. The responsibility that arises from the trainee's integration into the corporate practices of the respective company is a further structural advantage. While these advantages do not apply in the context of schools, they can be decisive especially for youths who have more difficulties with their education. Therefore, all stakeholders from the vocational education system are called upon to create sufficient job opportunities, either by providing traditional training places or, if necessary, by offering supportive measures during the transition from school to training.[69] In addition, the lower part of the ability distribution must be provided with attractive occupational profiles with adequately reduced requirements and shorter durations, complemented by specific measures to support the transition from school to working life. This would increase the chances of obtaining a qualification that can lead to subsequent qualifications. Existing programmes in this area should be evaluated and programmes should be integrated, to enhance transparency, and, as necessary, programmes should also be expanded.

In the upper part of the ability distribution, the future attractiveness of dual training pathways has to be secured in spite of the strong drift towards academic education. First and foremost, this can be achieved by providing clear-cut career options for vocational graduates. As a prerequisite, it is important to create and clearly communicate career advancement prospects through further training courses within the vocational system (Tertiary B) or through the permeability towards the university education system (Tertiary A).[70] In future, all qualifications should be designed in a way that allows for additional successive qualifications and, again, this must be made transparent and communicated more clearly. Businesses and universities need to participate in these efforts, and political decision-makers need to coordinate their educational policies accordingly.

Horizontal and vertical permeability plays a key role in securing the future of Germany's dual education system, as does the recognition of skills acquired in working life[71] and transparent access to higher education for qualified professionals without general university entrance qualification.[72] In this context, recent steps taken in developing recognition procedures should be continued further. The efficient use of existing recognition options should be systematically evaluated. In addition, access to universities for qualified professionals without university entrance qualifications *(Abitur)* should also be evaluated and made more transparent.

In future, Germany's education policy must focus on directing public awareness towards an optimal educational mix and flexible individual educational biographies rather than a mere increase in the proportion of university graduates. A stronger focus on an individually optimised education mix may also help alleviate the problem of high dropout rates in the tertiary education system.[73] During a difficult phase in their life, young people may have little interest in or aptitude for a purely academic pathway and will more likely consider entering into vocational education if they recognise that clear-cut development opportunities are provided. This would mean that they wouldn't have to put all their eggs in one basket and potentially risk failure within the higher education system. This way, false starts with potentially adverse, long-term effects on self-esteem can be prevented, and valuable occupational and non-cognitive skills can be gained instead. At a later stage, these skills can lead to additional successive qualifications based on individual preferences and through a variety of development opportunities.

Conversely, by entering into vocational training at a later stage, many dropouts from tertiary education institutions may also be provided with valuable future prospects during a difficult phase in their life. Even the crafts sector has realised that vocational training may represent an attractive alternative for the current high number of university dropouts, especially in cases where candidates are acutely lacking interest in or aptitude for a purely academic education. Thus, the Chambers of Crafts *(Handwerkskammern)* are increasingly creating programmes that aim to tap this potential. Here, partnership programmes with universities can increase the attractiveness of such alternative options. As part of a further differentiation of the German academic landscape – a measure that has been called for in the 2013 EFI

Report – individual universities could be provided with valuable opportunities to reposition themselves.[74]

Alternative means of financing the general education school system and the tertiary education system should also be considered to stop the strong drift away from the dual vocational education system; a drift that results from a downward spiral in performance standards in upper secondary schools and universities. In future, financing formulas should be based on quality measures and learning progress rather than on quantity measures, i.e. pupil or student numbers. Also, suitable indicator systems that integrate all levels of the German education system have to be developed.

In addition, regular external achievement tests focussing mainly on measuring learning progress, should be considered to be performed at all school levels and not just in the context of the centralised school-leaving examination *(Abitur)*. Such comparative assessments should be based on exogenous criteria – as is the case with e.g. PISA – and results should be made publicly available at school level. When introducing such external achievement tests, schools should also be granted more flexibility regarding the use of resources. Theoretical and empirical studies show that school autonomy combined with external achievement tests are the best means of ensuring that schools reach the intended objectives.

Finally, the above-mentioned developments and challenges must be documented more clearly by introducing advanced education indicator systems. Since its 2012 Report, the Expert Commission has also integrated professionals with non-academic (dual) training into the "qualification level of the European workforce" indicator. In addition, the Expert Commission is planning to record "on-the-job training" more closely, based on the IAB Establishment Panel *(Betriebspanel)* commissioned by the Institute for Employment Research (IAB). However, due to the available data, this indicator will be applied at national level only. Education indicator systems should be expanded further and should also be coordinated at international level. The aim is to record the performance of education systems with a vocational focus to a greater extent in international statistics and educational comparisons.

Recommendations

- Investments in maintaining and developing the attractiveness of vocational education should be continued.
- Young people with low educational qualifications and missed opportunities should be provided with additional entry-level and transitional measures for accessing the vocational education system. For the purpose of transparency, existing measures should be evaluated, more closely integrated and also expanded if necessary. Furthermore, young people should be provided with occupational profiles with reduced requirements and shorter durations which are compatible to subsequent additional qualifications.
- Talented, ambitious graduates from vocational training should be provided with clear-cut career options based on individual development opportunities and an increased permeability between different educational tracks.
- Future goals for the German educational system should focus on an optimal mix of different types of education and flexible individual educational paths, rather than the ratio of university graduates. To achieve these goals, new education indicators will have to be developed.
- Based on the foreseeable decline in the numbers of graduates from compulsory schooling, the financing formulas for upper secondary and tertiary education should in the future focus on schooling quality and learning achievements, rather than focussing on student enrolment numbers.
- Regular external achievement tests should be conducted at all levels of the general school system. These should aim to document the individual learning progress in particular. The results of these assessments should be made publicly available at school level. Such assessment tests should be combined with an increase in autonomy for schools in terms of allocating their resources.

A 4 STRUCTURE AND DEVELOPMENT OF THE KNOWLEDGE ECONOMY

Growth and employment in highly developed and relatively expensive business locations can only be secured through continuous innovation. First and foremost, this can be achieved in the knowledge economy, i.e. in research-intensive industries and knowledge-intensive services. This is the reason why many countries focus on generating an increasing share of value added in the knowledge economy.[75]

The Expert Commission regularly commissions studies on the German innovation system to determine the state of development of Germany's knowledge economy and to compare the sector's relevance and efficiency with that of important competitor countries. On average, the surveyed countries' share of the knowledge economy in total economic value added increased from 32 percent in 2000 to 34 percent in 2011. That said, there are particularly highly-developed countries (hereafter referred to as leaders in

FIG 02 **Share of research-intensive industries and knowledge-intensive services in value added between 2000 and 2011** (figures in percent)

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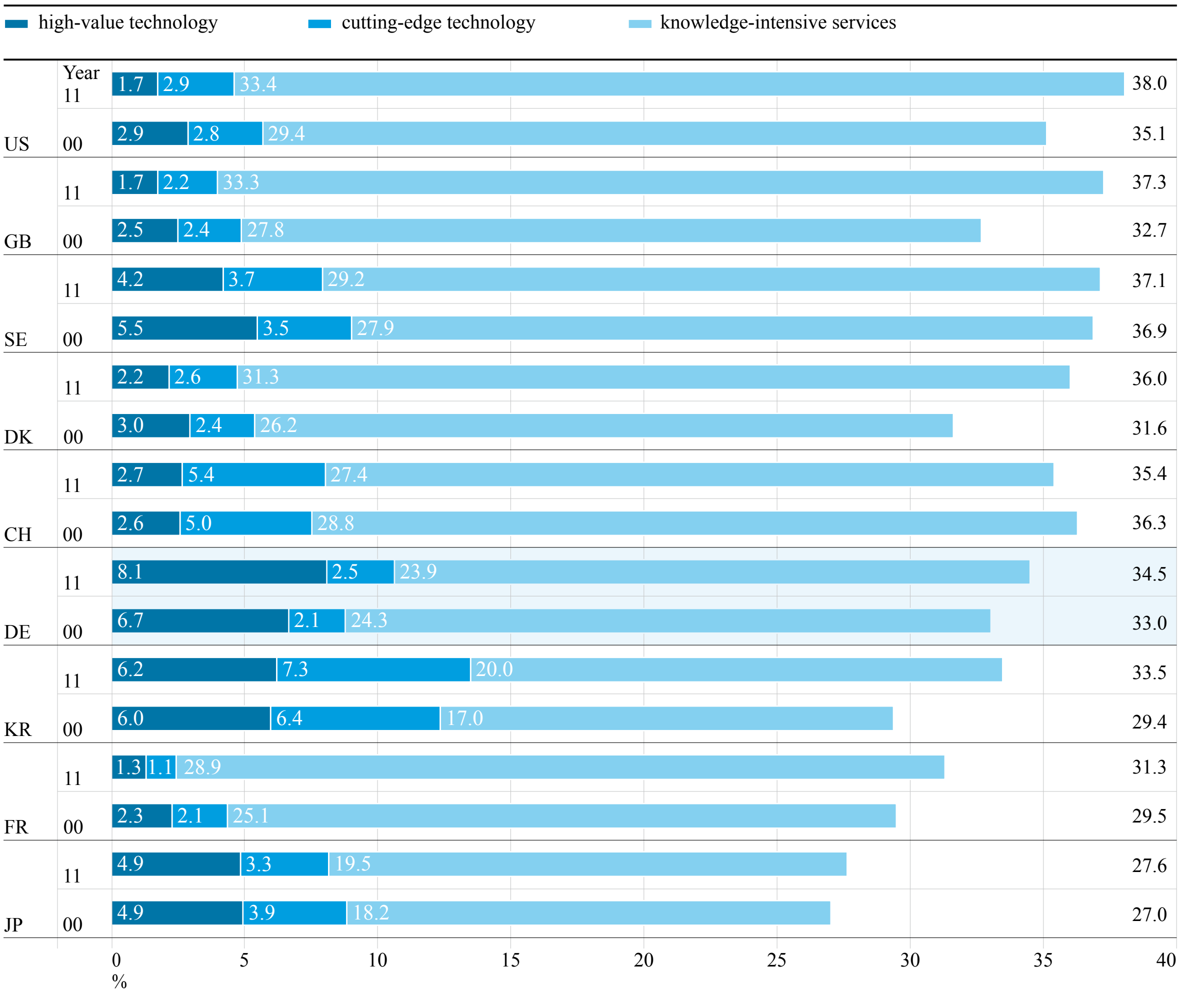

Source: OECD STAN (2013), Eurostat (2013), EUKLEMS (2013, 2007), BEA (2013), BOK (2013), Statistics Bureau - Ministry of Internal Affairs and Communications Japan (2013); calculations and estimates by DIW Berlin.

modernisation) that are characterised by a particularly rapid transition towards the knowledge economy. In these countries, the current share of the knowledge economy in total value added amounts to 37 to 38 percent. When it comes to developing the different segments of the knowledge economy, the surveyed countries also display differing development patterns. These differences are described in further detail below.

Figure 2 shows the ranking of countries, measured by the knowledge economy's share in national value added for the year 2011. Changes in this indicator and its main components are illustrated for the 2000 to 2011 period. With a share of 38 percent in value added, the United States are pioneering in expanding the knowledge economy; closely followed by Great Britain and Sweden (both at 37 percent), Denmark (36 percent) and Switzerland (35 percent). Germany has a 34.5 percent share in value added and has steadily increased the knowledge economy's share since 2000, albeit with different focal areas than the comparison countries.

Global economic momentum is characterised by the fact that also emerging economies are increasingly focussing on expanding their knowledge economies. Over the last decade, a consistent development towards the knowledge economy has taken place particularly in Korea, China, Brazil, Mexico and Russia, as well as Hungary, the Czech Republic and Poland. An increasingly large number of emerging economies are focussing on developing research-intensive industries and knowledge-intensive services as part of their development strategies.

Also in future, structural change will be characterised by the growing importance of the knowledge economy – both in highly developed countries and in emerging economies. Germany's success in securing growth and employment essentially depends on its ability to retain its position in the interplay of forces between highly developed leaders in modernisation and ambitious emerging economies. For Germany, it will not suffice to solely rely on proven strengths in R&D-intensive manufacturing industries. The following analysis demonstrates that Germany will have to step up its efforts particularly in the field of knowledge-intensive services.

R&D-intensive industries in international comparison

Germany still maintains its position in the knowledge economy, which is largely owing to industry, a sector that remains to be strong. The industry sector was further advanced between 2000 and 2011, partially at the expense of the knowledge-intensive services' share in value added (cf. Figure 2). In Germany, the share of R&D-intensive industries in national value added amounts to 10.6 percent and is thus significantly higher than in the United States, Great Britain, France and the Scandinavian countries.[76] That said, Germany concentrated its efforts on selected fields from among the R&D-intensive industries. Thus, the German economy continues to be particularly strong in high-value technology, as illustrated by the dark blue bar on the left in Figure 2. The share of this manufacturing industry segment once again significantly increased between 2000 and 2011, which contrasts with developments in the other countries surveyed. With its 8.1 percent share of high-value technology in national value added, Germany claims an impressive top position. Other countries reduced their shares of high-value technology in the surveyed period and tend to show significantly lower values in this respect: the share of high-value technology in value added amounts to only 1.7 percent in the United States and in Great Britain, 1.3 percent in France and 4.9 percent in Japan.

Germany's existing strengths in the area of high-value technologies stand in contrast to its shortcomings in the area of cutting-edge technology (as illustrated by the central bar in Figure 2). Here, Germany plays a subordinate role, while many other countries have in fact strengthened their efforts in developing cutting-edge technology in recent years. Only a 2.5 percent share in Germany's value added is attributable to cutting-edge technologies, in marked contrast to e.g. Korea (7.3 percent), Switzerland (5.4 percent) and Sweden (3.7 percent). Deficits in the field of cutting-edge technologies can also be observed in other large EU countries. Thus, the share of high technology in Great Britain's value added stands at only 2.2 percent, and 1.1 percent in France. The European Union as a whole also shows significant deficits in this area.[77]

Knowledge-intensive services

In nearly all of the countries surveyed, knowledge-intensive services make up the largest share of the knowledge economy. These include know-how-intensive services in the area of IT, finance, healthcare, and business services. Many countries have been concentrating their development strategies on expanding these sectors, especially the United States, where knowledge-intensive services now account for 33.4 percent of value added. The relevance of knowledge-intensive services is also relatively high in Great Britain (33.3 percent), Denmark (31.3 percent), the Netherlands (30.1 percent) and France (28.9 percent). With a share of 23.9 percent, knowledge-intensive services in Germany are still significantly underrepresented when compared with the above countries. What is more, the share of knowledge-intensive services in value added declined in Germany between 2000 and 2011, in stark contrast to the development in many of the surveyed countries. Germany's future competitiveness depends crucially on also further expanding the knowledge-intensive services sector.

Productivity development in international comparison
A favourable position in international competition is the main prerequisite for securing and increasing prosperity in Germany. This is largely driven by the development of productivity. Over the past decade, key leaders in modernisation have increased their productivity, especially in the knowledge economy. These countries have also benefitted from spillover effects from the knowledge economy, which has led to strong productivity gains in downstream sectors of the economy. In terms of productivity development, the period between 1995 and 2006 displays significant differences between Europe and the United States. This is largely attributable to the fact that the United States considerably expanded their knowledge economy, and particularly in the ICT industries.[78]

Development of labour productivity in research-intensive industries

Figure 3 shows that labour productivity in research-intensive industries increased particularly sharply in the United States and in Sweden (between 2000 and 2011), as well as in Japan (up to 2008). Germany, Great Britain, France and Switzerland recorded relatively smaller increases in labour productivity in the same period, which, in Germany, was mainly caused by productivity losses during the financial crisis in 2008/2009.

Development of labour productivity in knowledge-intensive services

Also in the area of knowledge-intensive services, productivity developments differed considerably between European countries and non-European leaders in modernisation. In addition, major differences between individual European countries can also be observed. While Germany did not manage to increase labour productivity in knowledge-intensive services over the last decade, the United States, Great Britain and Sweden recorded a very substantial increase in this regard (cf. Figure 4).[79]

Within the BRIC countries and other emerging economies, there are also significant differences in terms of productivity development in knowledge-intensive services. Especially China and India, but also Russia recorded strong increases in productivity, while Brazil and Korea fell slightly behind in this area.[80]

Recommendations

In the coming years, Germany's international competitiveness will crucially depend on the expansion of the knowledge economy and its spillover effects on other sectors of the economy. Germany's existing strengths in the area of high-value technologies should be supplemented by complementary developments in the field of cutting-edge technology and knowledge-intensive services. Service innovation, new business models and systematic internationalisation strategies can help increase productivity in knowledge-intensive services.

The German research and innovation policy needs to significantly improve conditions for cutting-edge technologies. This requires enhanced efforts in the fields of entrepreneurship, innovation and growth financing, as well as R&D tax credits. Germany should also focus on attracting direct investment from foreign companies in those areas where German companies display insufficient development. Especially in the areas of cutting-edge technology and knowledge-intensive services, dynamic investors should be

Development of labour productivity in research-intensive industries (2000 = 100)

FIG 03

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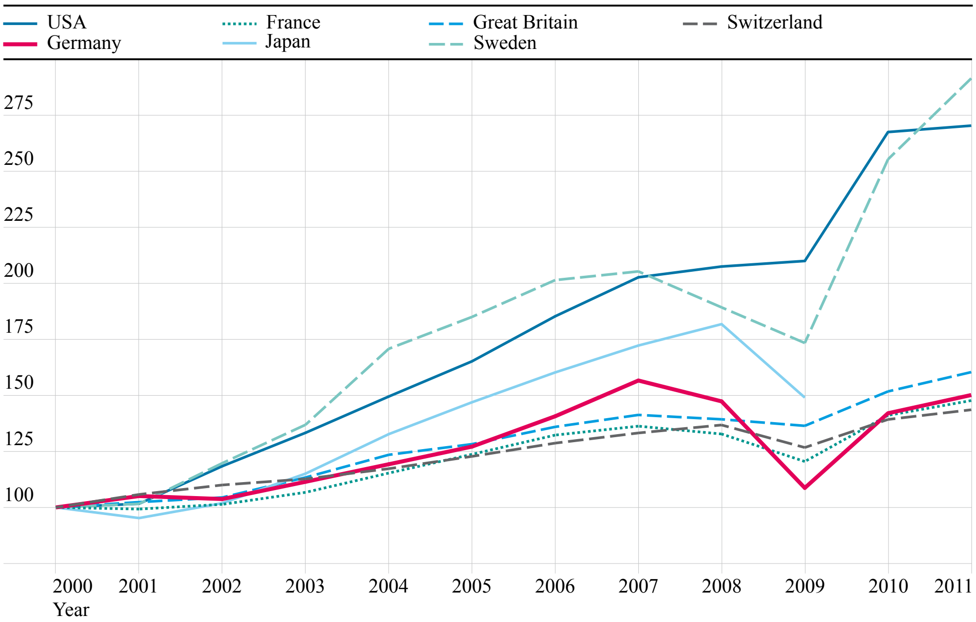

Source: OECD STAN (2013), Eurostat (2013), EUKLEMS (2013, 2007), BEA (2013), Statistics Bureau - Ministry of Internal Affairs and Communications Japan (2013); calculations and estimates by DIW Berlin. Data on Japan only available up until and including 2009.

Development of labour productivity in knowledge-intensive services (2000 = 100)

FIG 04

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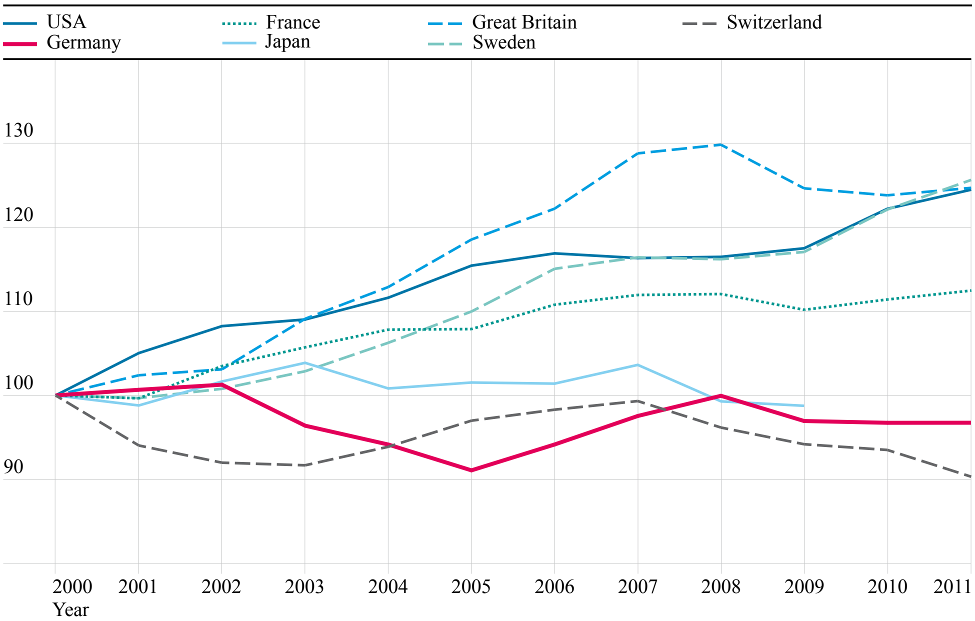

Source: OECD STAN (2013), Eurostat (2013), EUKLEMS (2013, 2007), BEA (2013), Statistics Bureau - Ministry of Internal Affairs and Communications Japan (2013); calculations and estimates by DIW Berlin. Data on Japan only available up until and including 2009.

encouraged to establish locations in Germany and to collaborate with German businesses and research institutions.

Even more than in the past, companies in Germany need to focus on applying the most recent information and communication technologies as a means of developing productivity. A close integration of technological innovations and organisational development processes is crucial for achieving high productivity gains.[81] High priority should be attached to the development of information and communication technologies in Germany and their utilisation in other areas of the economy and society (cf. Chapter B 3). Furthermore, the expansion of the knowledge economy should not be pursued in isolation from the upstream and downstream sectors of the economy. A number of countries have systematically developed their knowledge economies, but these often remain relatively isolated from the more traditional economic sectors. The modernisation of the knowledge economy should also be used for creating spillover effects and productivity gains in non-knowledge-intensive sectors of the economy.

A 5 INTERNATIONALISATION OF RESEARCH AND DEVELOPMENT

Current developments of foreign research and development activities by German companies [82]

The internationalisation of research and development (R&D) of German companies has increased significantly in recent years. In 2011, German companies spent a total of EUR 14.8 billion on R&D in other countries. The share of foreign spending in global R&D expenditure thus rose from 27.3 percent to 30.5 percent between 2007 and 2011.

Between 2009 and 2011, German foreign R&D expenditure increased by 15.3 percent per annum. In comparison, domestic R&D expenditure by German companies increased by only 5.7 percent. German R&D activities abroad experienced a particularly strong increase in the automotive industry (an increase of 27.6 percent per annum), in mechanical engineering (25.1 percent per annum) and in the chemical industry (13 percent per annum). However, in contrast to previous years, international activities in the pharmaceutical industry and in electrical engineering increased only slightly.[83]

Data on international R&D activities of German companies are published by the *Stifterverband für die deutsche Wissenschaft* (Donors' Association for the Promotion of Sciences and Humanities in Germany). These data include figures on approximately 100 leading companies active in research. To determine the foreign R&D expenditure of these companies, global R&D expenditures are derived from the annual reports of these companies and compared with existing figures from the survey on domestic R&D expenditure.

The available data can also be analysed according to the industries the companies are active in. The majority of foreign R&D expenditure is attributable to the vehicle construction industry (EUR 5.9 billion, or 40 percent of total foreign R&D expenditure of German companies), followed by the chemical and pharmaceutical industries (EUR 5.0 billion in total, or 34 percent).

However, these data do not provide information on the particular countries in which German companies conduct their R&D activities. To address this issue and other open questions, the Expert Commission conducted a special survey in cooperation with the Stifterverband.

United States most important target country for German R&D – growing importance of China[84]

The companies participating in the special survey spent a total of EUR 7.2 billion on foreign R&D in 2011.[85] Thus, the survey records about 50 percent of German companies' foreign R&D expenditure. However, the companies included in the survey do not reflect the industry structure as displayed in the Stifterverband's comprehensive data collection: over 70 percent of the foreign R&D expenditure recorded in the survey was attributable to the chemical and pharmaceutical industries, and a mere 19 percent was attributable to the automotive industry and other transport equipment.

While the special survey thus represents only a portion of the overall picture, it allows for additional insights due to the survey's depth and its qualitative components.

Based on the level of expenditure, the United States are the most important target country for German companies' foreign R&D activities. Austria, Switzerland, Japan and France follow at a significant distance, and China and India hold sixth and seventh position respectively. However, the ranking changes when based on the number of times a country is mentioned: while the United States remain the most important target country, China is now in second place.

At 14 to 45 million EUR per company on average, the level of R&D expenditure allocated to highly developed countries such as the United States, France and Japan continues to be significantly higher than that allocated to the BRIC countries.[86] R&D locations established in the BRIC countries still tend to show relatively low investment volumes.

German companies invest an average amount of nine to ten million EUR in China and India, two million EUR in Brazil and substantially smaller amounts in Poland and Russia.

The tapping of knowledge and markets as key driving forces for foreign R&D

The surveyed companies were asked which motives were relevant for their decision to conduct R&D abroad. The tapping of new markets as well as the tapping of specific knowledge or skilled workers in the target country were most frequently considered relevant motives.[87] Lower regulatory requirements in the target country and political requirements set by the target country's government were considered as least relevant.[88]

That said, companies do not consider all of these motives as equally relevant for all target countries or groups of countries. The tapping of new markets proves especially significant for investments in the United States and the BRIC countries: approximately 80 percent of companies conducting R&D in these countries consider this motive as relevant. The proportion is only about half as high for the EU-14[89] and Eastern Europe[90] (43 and 44 percent, respectively). The tapping of specific knowledge or skilled workers in the target country is the most relevant motive for R&D activities in the EU-14 and the United States (61 and 65 percent, respectively). Savings in wages and non-wage labour costs are relevant motives for investments in Eastern Europe: 85 percent of companies conducting R&D activities in this region consider this motive as relevant, and nearly two thirds of companies consider this a relevant motive for R&D activities in the BRIC countries.

The survey also revealed that motives for investing abroad do not only differ according to target country, but also according to industry. Especially in the chemical, pharmaceutical and automotive industries, as well as other transport equipment, engineering and technical services, the tapping of new markets is frequently considered a relevant motive. The tapping of specific knowledge or skilled workers in the target country is by far the most relevant motive for the ICT industries as well as for engineering and technical services.

Foreign R&D in the BRIC countries to be further expanded despite restraints

The surveyed companies were also asked which difficulties and obstacles they face when conducting R&D activities abroad.[91] Overall, the surveyed companies expressed only little concern. Yet, it should be noted that the companies surveyed are not representative in this respect, since nearly all of the companies have been engaged in foreign R&D for at least five consecutive years. This means that the surveyed companies represent a selected group of companies with a successful record of foreign R&D activities.

The obstacles most frequently considered as relevant are cultural or language barriers (27 percent), followed by insufficient training of skilled workers (22 percent) and academics (18 percent).

The surveyed companies also assessed the relevance of obstacles and difficulties differently according to target countries and groups of countries. Obstacles and difficulties in the BRIC countries are most frequently considered as relevant, followed by Eastern Europe. With regard to the EU-14, obstacles and difficulties are considered less significant, and this also applies to locations in the United States. Merely insufficient training of skilled workers is considered to be an issue here. Almost a quarter of German companies conducting R&D in the United States consider this a relevant obstacle. The training of academics, however, was assessed positively throughout.

Finally, businesses were asked about their plans for the next five years. Many of the companies intend to keep their R&D commitments in foreign locations constant (56 percent). According to the companies, activities in 36 percent of foreign R&D locations are to be expanded, and in only 8 percent of cases activities are to be reduced. Companies with R&D commitments in the BRIC countries are more likely to plan an expansion of their respective activities in the future (67 percent of companies). There are hardly any differences to be observed across industry sectors.

Recommendations

From a research, education and innovation policy perspective, the question arises whether the observed trends in foreign R&D activity are accompanied by a strengthening or weakening of Germany as a research location. An increase in R&D commitments abroad would be an issue if it were accompanied by a drain of domestic knowledge and skills. Analyses to date, however, show that Germany still holds a balanced position overall.[92] In 2011, foreign companies invested even more in R&D in Germany (EUR 16.2 billion) than German companies invested abroad (EUR 14.8 billion).[93] In the view of the Expert Commission, there is no immediate need for action in this field.

It is a cause of concern, however, that in the field of cutting-edge technology German companies increasingly conduct their R&D in other countries. German companies are stepping up their foreign R&D investments especially in the highly dynamic areas of information and communication technologies, biotechnology, genetic engineering and, more recently, medical research. These industries will be analysed in more depth in Chapters B 1 and B 3.

As will be shown in Chapter B 2, Germany is currently losing a considerable number of scientists and inventors in the field of cutting-edge technology to foreign countries. In turn, German businesses, especially in ICT, are relocating their R&D sites to precisely those countries in search of top talent. These developments reinforce each other and permanently weaken Germany as an innovation location. The Expert Commission would like to point to the dangers of a competence trap caused by excessive specialisation in areas that are currently highly competi-tive – at the expense of areas that might be highly relevant in the future.

The Expert Commission reiterates that it is of central importance for German R&I policy to retain talented innovation professionals, whether it is scientists and inventors, in Germany, or to recover them from abroad, respectively. Measures relating to such efforts (cf. Chapters B 2 and B 3) must be coupled with incentives in order for international companies to become active in the field of cutting-edge technologies in Germany.

A 6 ELECTROMOBILITY: SOME ACHIEVEMENTS, AND A LOT MORE TO DO

The development of the transport sector towards climate and environmentally friendly electromobility is considered central to the sustainability of future energy systems.[94]

For Germany as an "automotive country", this development presents a key challenge. Considerable efforts will be required to transfer technological leadership in conventionally powered vehicles to the new markets for electrically powered vehicles. The traditional automotive industry currently generates around 16 percent of Germany's industrial value added.[95] This sector employs ca. 740,000 people, and if one includes the supply industry, this figure rises to almost two million.[96]

Since 2009, politics and industry have considerably strengthened their efforts to promote electromobility with the goal of establishing Germany as the leading market and supplier in this sector. To this end, the Federal Government concluded the National Electromobility Development Plan in August 2009, financing it to the tune of 500 million EUR in the period to 2011. Industry representatives also committed themselves to wide-ranging investments.[97] Furthermore, approximately one billion EUR in additional public funding has been earmarked for the period up to 2014. As a result, a number of research centres for high-performance batteries have been established or expanded, and numerous joint research projects have been initiated.

In 2010, the National Platform for Electromobility (NEP) was established, composed of top representatives from industry, science, associations and politics, with the aim of coordinating and implementing the National Development Plan.[98] Individual federal states have also initiated programmes for the promotion of research activities and the market entry of electric vehicles.[99]

The National Electromobility Development Plan has set itself the goal of placing one million electric vehicles on Germany's streets by 2020. The one million target is to be reached in three phases. The market preparation phase, running through to 2014, is characterised by a number of support programmes. In eight model regions, different approaches to the development of infrastructure and the integration of electromobility in the public sphere are being supported.[100] In four major demonstration and pilot projects – so-called showcase projects – electromobility technologies and concepts are being examined for their practicality, user acceptance and environmental impact.[101] R&D funding is organised in a range of categories, which are referred to as lighthouses. These include battery, propulsion technology and vehicle integration, lightweight construction, recycling, and ICT.[102] A market launch phase is planned for the period before 2017. By 2020 a mass market for electromobility is to be established. Industry has committed up to 17 billion EUR in electromobility-related research and development for the market preparation phase.[103]

In its 2010 and 2011 Reports, the Expert Commission explicitly welcomed the concerted efforts of politics and industry – in particular the announcement of massive investment in research and development. At the same time it pointed to deficits in scientific and technological developments. This especially applies to research in the areas of high-performance electronics and high-performance batteries. These represent key electromobility technologies and make up a large part of industrial value added.

Current developments in Germany

The total number of electric vehicles in Germany is currently very low. At the start of 2013, there were only ca. 16,000 electric vehicles (electrically powered cars, plug-in hybrids, motorcycles, vans and buses) in use.[104]

The recommendations of the Expert Commission[105] to provide tax incentives for the purchase of company cars with electric or hybrid motors were incorporated into the 2013 German Annual Tax Act. With respect to the taxation of the monetary advantage from the private use of company cars, the cost for the batteries – the most expensive single component –

was deducted from the list price. The high number of model regions, criticised by the Expert Commission[106] because of the risk of fragmentation, was reduced from seventeen to eight.

Can one million electric vehicles be put on the streets by 2020?

A study by the Fraunhofer Institute for Systems and Innovation Research (ISI), commissioned by the Federal Ministry of Economics and Technology (BMWi), has examined the diffusion of electric vehicles under different framework conditions. In addition to fuel, electricity and battery prices, factors such as the choice of models, willingness to pay more and the battery charging infrastructure were also included.[107] According to the study, under favourable conditions the goal of one million electric vehicles can be reached without additional measures. Under unfavourable conditions the authors of the study still predict between 150,000 and 200,000 vehicles. The authors see significant potential for the deployment of electric vehicles in commercial fleets, which make up around 30 percent of the new car market. This area displays favourable operational profiles for the use of electric vehicles, with high annual mileage composed of predictable short and medium length journeys. In this context, the provision of public and semi-public battery charging infrastructure plays a less important role. Furthermore, existing depreciation options and a lower purchase price due to exemption from VAT increase the attractiveness of electric vehicles.

Status of research on high-performance electronics and high-performance batteries

The Expert Commission's 2010 Report investigated the number of patent applications and publications in internationally renowned journals in order to assess the performance of the German research system in the two key technologies of high-performance electronics and high-performance batteries, drawing an international comparison for the period up to 2007. Germany only achieved a middle position in research into high-performance electronics and was far down the ranking for battery research. The updated analysis of patent applications (up to 2011)[108] and publication activities (up to 2012) shows mixed results. Across the globe, both technology fields are undergoing a very dynamic development. While Germany is not keeping pace with developments in high-performance electronics, it is gaining significant ground internationally with its battery research.

Patent applications as well as publications in the area of high-performance electronics display a positive trend worldwide (Figures 5 and 6). However, Germany's share of patent applications, averaged over three years, has declined slightly since 2007. The analysis of publication activity also fails to show any marked improvement since 2009. Consequently, the measures initiated since 2009 to promote electromobility have not yet resulted in increased publication activity in the field of high-performance electronics. However, it is too early to undertake a final assessment of the Federal Government's support measures.

The updated analysis for the field of high-performance batteries indicates above-average activity for German patent applications between 2007 and 2011. With strong global growth – the number of patent applications worldwide almost tripled between 2007 and 2011 – Germany's average share of applications, calculated over three years, shows a positive trend for this period. The analysis of publication activity points in the same direction. This has also displayed a clear upward trend since 2007. The development of German research in the area of high-performance batteries is thus to be assessed as positive. However, on the basis of this data it is again not possible to provide a conclusive assessment of the contribution of public research support measures since 2009.

The fuel cell – another propulsion technology option for electric vehicles

In addition to high-performance batteries, the fuel cell could also become established as an electromobility propulsion technology in the medium to long term. Studies which explicitly consider electric vehicles powered by fuel cells have predicted significant, long-term market advantages for this propulsion technology.[109] The main competitive advantage of the fuel cell over high-performance batteries is the greater range and the shorter fuelling time compared to battery charging times. A number of car manufacturers, e.g. Daimler, Ford, Toyota and Honda, are currently pushing ahead with the development of fuel-cell powered electric vehicles.[110]

FIG 05 **Number of worldwide transnational patent applications and internationally renowned publication in the field of high-performance electronics**
(updated figures up until 2011 (patents) and 2012 (publications))

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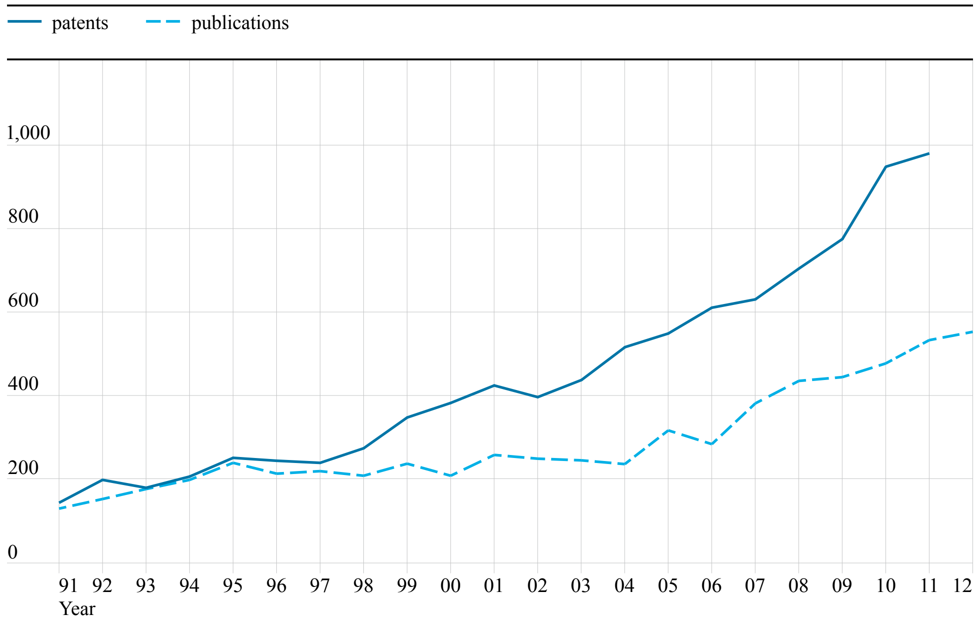

Source: Patents: own depiction based on WPINDEX (STN), own surveys and calculations.
Publications: own depiction based on SCISEARCH (STN), own surveys and calculations.

FIG 06 **Germany's percentage share in transnational patent applications and internationally renowned publications in the field of high-performance electronics**
(updated figures up until 2011 (patents) and 2012 (publications); Germany's share averaged over three years due to high variance)

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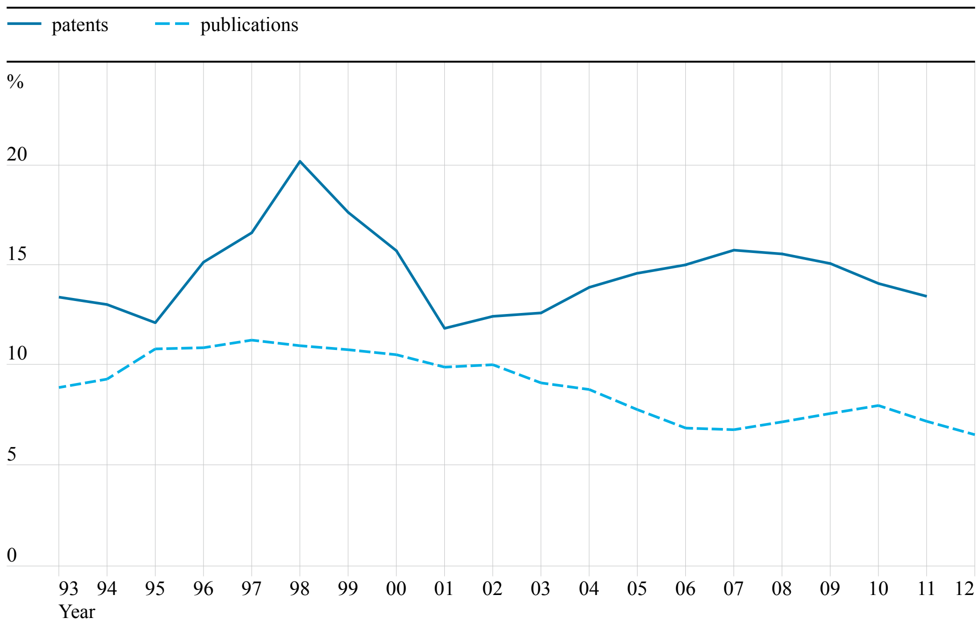

Source: Patents: own depiction based on WPINDEX (STN), own surveys and calculations.
Publications: own depiction based on SCISEARCH (STN), own surveys and calculations.

Number of worldwide transnational patent applications and internationally renowned publications in the field of high-performance batteries
(updated figures up until 2011 (patents) and 2012 (publications))

FIG 07

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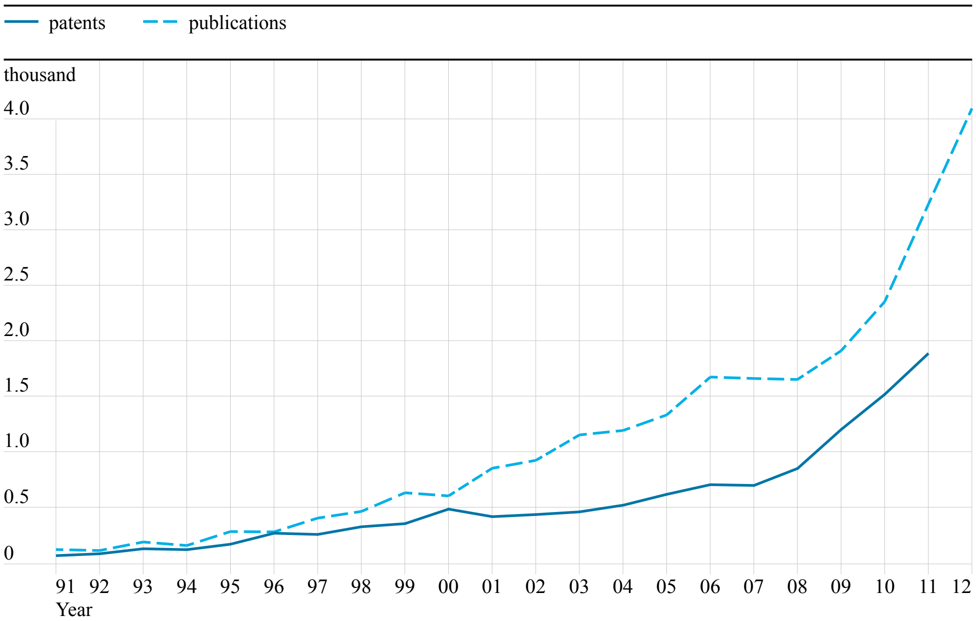

Source: Patents: own depiction based on WPINDEX (STN), own surveys and calculations.
Publications: own depiction based on SCISEARCH (STN), own surveys and calculations.

Germany's percentage share in transnational patent applications and internationally renowned publications in the field of high-performance batteries
(updated figures up until 2011 (patents) and 2012 (publications); Germany's share averaged over three years due to high variance).

FIG 08

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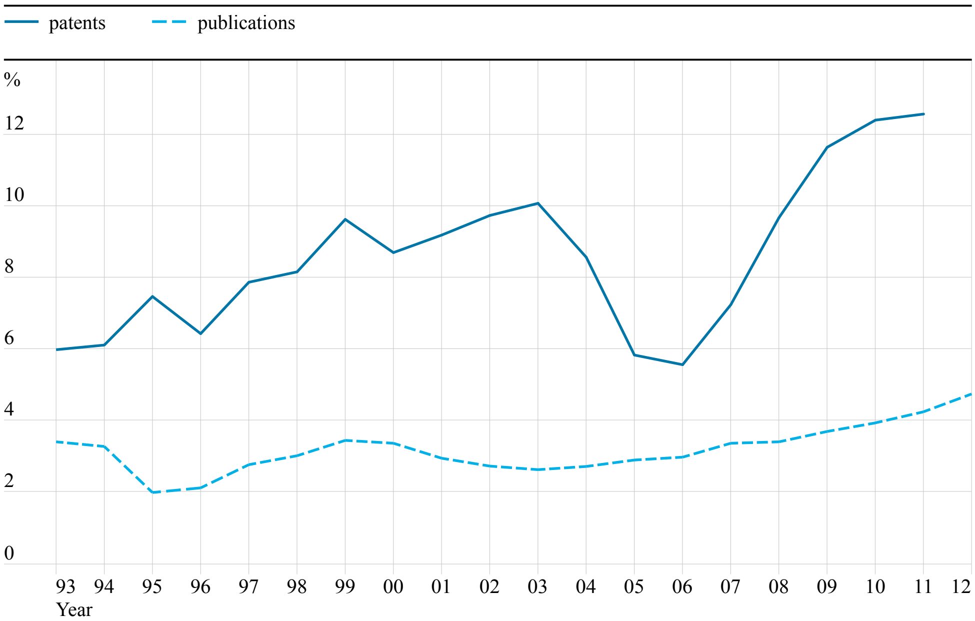


Source: Patents: own depiction based on WPINDEX (STN), own surveys and calculations.
Publications: own depiction based on SCISEARCH (STN), own surveys and calculations.

However, this technology requires a comprehensive network of hydrogen filling stations.[111]

Developments in the electromobility market are closely intertwined with the future design of the electricity supply system. Consequently, the type of technology – high-performance batteries or fuel cells – which becomes established in the mobility sector, and the depth of market penetration, are of great relevance for the electricity supply from renewable energies. A mass market for battery-powered vehicles could contribute to the stabilisation of the distribution networks by deploying the vehicles' electricity storage capacity to buffer the fluctuating electricity supply form renewable energies. At the same time, this poses the challenge of avoiding peaks in electricity demand which could result from users loading their batteries at the same time – for example in the evenings after work. That said, a mass market for fuel cell vehicles would interact positively with an infrastructure for the hydrogen supply, which in the electricity sector could arise from the large-scale deployment of power-to-gas technologies.[112]

German fuel cell research is publicly funded, amongst other sources, by the National Hydrogen and Fuel Cell Technology Innovation Programme (NIP), initiated in 2006.[113] The projects funded by the programme are bundled and coordinated by the National Organisation Hydrogen and Fuel Cell Technology (NOW) platform, founded in 2008.[114] The total budget of the ten year NIP programme (2006–2016) is EUR 1.4 billion, of which just under 60 percent is allocated to the "Transport and Infrastructure" programme area. Half of the budget is provided by the Federal Ministry of Transport, Building and Urban Development (BMVBS) and the Federal Ministry of Economics and Technology (BMWi), the other half by industry. The NIP supports both R&D and demonstration projects.[115]

If one assesses German innovation activity in the area of fuel cells according to the same criteria as those applied to high-performance electronics and batteries, the picture is sobering.[116] During the highly dynamic global growth in transnational patent applications in the 1990s, Germany's share of applications, averaged over three years, rose to nearly 30 percent in 1997. Between 2000 and 2011, worldwide applications exhibited a downward trend and the German share has generally fluctuated between 10 and 15 percent – with a current downward trend. The analysis of the publication data shows a steady increase in publications worldwide over the last 20 years. However, in contrast, the German share has fallen continually since the start of the millennium. A possible reason for this is that Germany's R&D strategy in this sector has a strong focus on close-to-market projects, often with a high demonstration character, while more innovation-oriented research plays a less prominent role.[117]

Recommendations

In recent years, Germany has launched major electromobility research programmes in the fields of high-performance electronics, high-performance batteries and fuel cells. The development of research activities in the area of high-performance batteries – measured in terms of patent applications and publications – is positive. As regards high-performance electronics and fuel cells, it is not possible to observe any improvement in patent applications and publications as indicators for innovation activity, which might be due to the strong product orientation of current R&D activities. However, it is too early to provide a conclusive assessment of the effectiveness of research support programmes as patent applications and publications often require a considerable lead time.

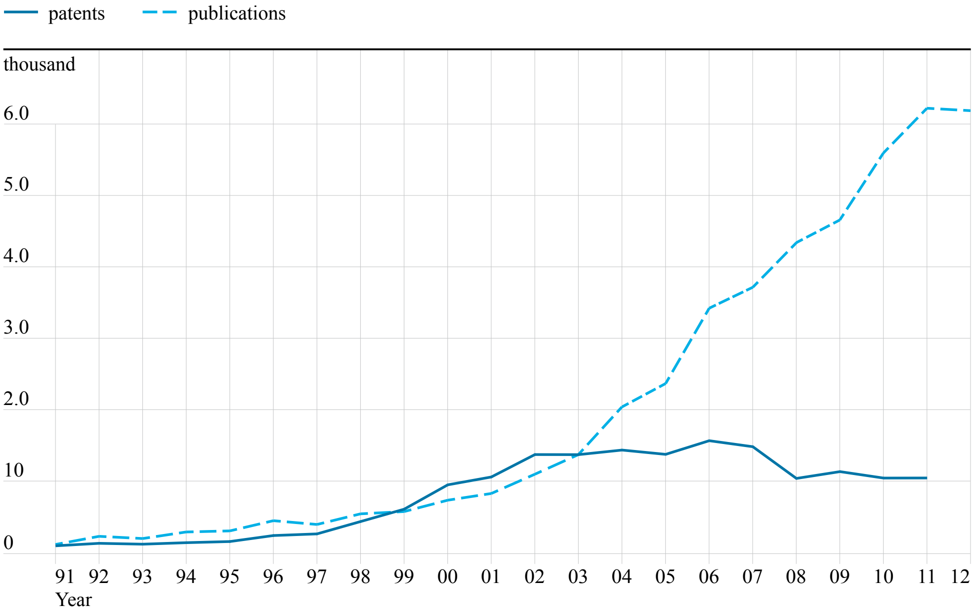
In recent years, efforts to introduce electromobility have been focussed on battery-powered vehicles.[118] In the long term, research funding policy should be technology open, i.e. it should not discriminate between research in the fields of high-performance batteries and fuel cells. The Expert Commission welcomes the fact that this is also anchored in the coalition agreement.[119] Funding of the "National Hydrogen and Fuel Cell Technology Innovation Programme" expires in 2016. Following a review of the measures' effectiveness and an assessment of future potential, a continuation of funding would be expedient in order to preserve the know-how developed in Germany and successfully support market launch.

The interface between electromobility (whether on the basis of batteries or fuel cells) and electricity networks is of central importance. Mutual dependencies exist between grid management and energy storage technologies, respectively, and propulsion technologies for electric vehicles. The research and

Number of worldwide transnational patent applications and internationally renowned publications in the field of fuel cell technology
(updated figures up until 2011 (patents) and 2012 (publications))

FIG 09

DATA DOWNLOAD

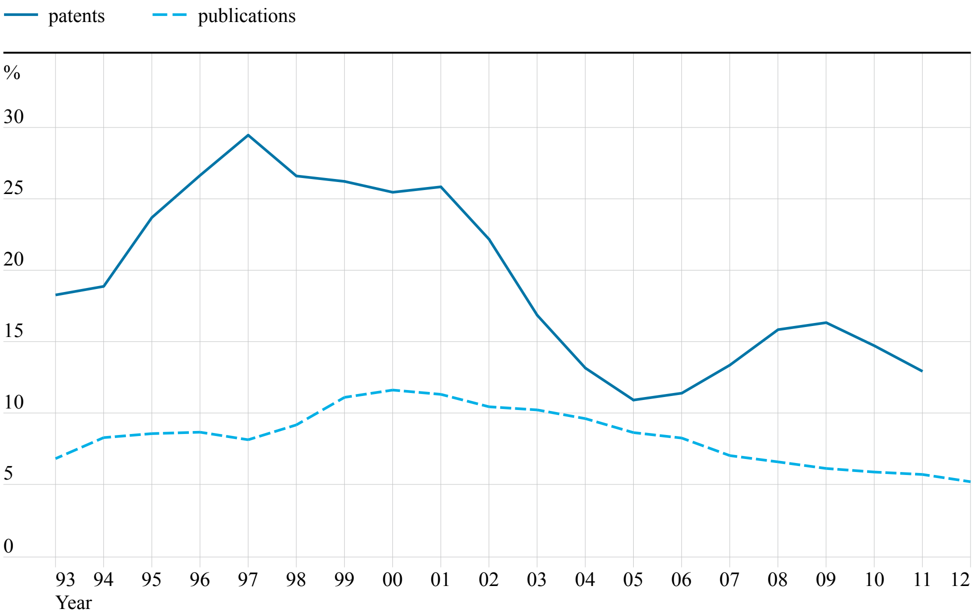


Source: Patents: own depiction based on WPINDEX (STN), own surveys and calculations.
Publications: own depiction based on SCISEARCH (STN), own surveys and calculations.

Germany's percentage share in transnational patent applications and internationally renowned publications in the field of fuel cell technology
(updated figures up until 2011 (patents) and 2012 (publications);
Germany's share averaged over three years due to high variance).

FIG 10

DATA DOWNLOAD



Source: Patents: own depiction based on WPINDEX (STN), own surveys and calculations.
Publications: own depiction based on SCISEARCH (STN), own surveys and calculations.

development of integrated technology concepts should be driven forward. This represents an important starting point for public coordination and public funding of research cooperation between car manufacturers, electricity supply companies as well as tertiary education institutions and non-university research institutions.

The Expert Commission welcomes the fact that the coalition agreement has distanced itself from buyer's premiums for electric vehicles and calls for the continuation of public R&D support programmes.[120]

Electromobility represents an important field of application for ICT. A close integration of research programmes on electromobility and ICT should be conducted as part of the Federal Government's Digital Agenda.

A 7 THE EEG FROM AN INNOVATION POLICY PERSPECTIVE

The Renewable Energy Sources Act (EEG): a brief stocktaking

The Renewable Energy Sources Act (EEG) is one of the key instruments of German climate and energy policy. The core elements of the EEG are the system operators' obligation to provide connection to the grid, priority feed-in of electricity from renewable energy sources over electricity from conventional energy sources, as well as technology-specific fixed feed-in tariffs and optional market premiums.[121] The difference between the market price and the compensation paid to the operators of power plants is borne by the electricity consumers via the EEG reallocation charge.

The EEG's policy objective is to achieve a share of renewable energy in gross power production of 35 percent by 2020 and of 80 percent by 2050. The EEG's promotion of renewable energy on the demand side has led to a rapid expansion of renewable energies in Germany – especially in wind power, photovoltaic and biomass.[122] Since the adoption of the EEG in 2000, the share of renewable energy in Germany's gross power production increased from less than 7 percent to approximately 23 percent in 2012.[123]

Since the adoption of the EEG, compensation paid to plant operators increased from EUR 1.6 billion in 2001 to EUR 22.9 billion in 2013 (cf. Table 1).

EEG compensation payments to plant operators and EEG reallocation charge between 2000 and 2013

TAB 01

DATA DOWNLOAD

EEG compensation payments to plant operators (million EUR)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Hydropower	–	442	477	428	338	364	367	418	379	382	421	231	452	487
Onshore wind energy	–	956	1,435	1,696	2,301	2,441	2,734	3,508	3,561	3,389	3,316	4,165	4,981	5,360
Offshore wind energy	–	–	–	–	–	–	–	–	–	6	26	85	119	471
Photovoltaics	–	39	82	154	283	679	1,177	1,597	2,219	3,157	5,090	7,766	9,202	10,420
Biomass	–	140	232	327	509	795	1,337	2,162	2,699	3,700	4,240	4,476	6,267	6,051
Landfill gas, sewage gas, mine gas	–	0	0	0	182	219	196	193	156	143	83	36	98	108
Geothermal energy	–	–	–	–	0	0	0	0	3	4	6	4	6	18
Total	**883**	**1,577**	**2,226**	**2,604**	**3,612**	**4,498**	**5,810**	**7,879**	**9,016**	**10,780**	**13,182**	**16,763**	**21,125**	**22,914**

EEG reallocation charge (cent/kwh)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Hydropower	–	0.06	0.07	0.05	0.04	0.04	0.04	0.03	0.02	0.01	0.05	0.03	0.06	0.05
Onshore wind energy	–	0.15	0.23	0.24	0.34	0.33	0.32	0.36	0.3	0.18	0.42	0.52	0.79	0.74
Offshore wind energy	–	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.09
Photovoltaics	–	0.01	0.02	0.03	0.06	0.15	0.25	0.34	0.47	0.67	1.13	1.81	2.06	2.25
Biomass	–	0.02	0.04	0.05	0.08	0.12	0.2	0.32	0.39	0.53	0.78	0.89	1.23	1.13
Landfill gas, sewage gas, mine gas	–	0	0	0	0.02	0.02	0.02	0.01	0.01	0	0.01	0	0.01	0.01
Geothermal energy	–	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**0.19**	**0.25**	**0.36**	**0.37**	**0.55**	**0.67**	**0.83**	**1.07**	**1.19**	**1.4**	**2.05**	**3.53**	**3.59**	**5.28**

Source: own depiction based on BMU (2013).

In particular subsidy payments to photovoltaics and biomass exhibited disproportionate annual growth rates of almost 60 and 35 percent, respectively – compared with an already strong average growth rate of 25 percent per year across technologies. The flip side of the coin is the drastic increase in the EEG reallocation charge. Today, more than a fifth of average electricity prices paid by consumers are attributable to the EEG reallocation charge. This considerable additional burden on consumers has led to a critical public debate on the rationalisation of the EEG.[124]

The climate protection argument, which is often cited to legitimise the EEG, does not hold true. The European emissions trading system (EU ETS) defines a fixed EU-wide ceiling for CO_2 emissions across energy-intensive industries. The expansion of renewable energies in Germany's power supply induced by the EEG therefore does not result in additional CO_2 emission reduction at the EU level, but merely shifts emissions to other sectors and other EU countries covered by the EU ETS. Thus, the EEG does not lead to more climate protection, but just induces additional cost.[125]

The EEG's technology-specific innovation effects in Germany are very low

Since the argument of climate protection does not qualify as a justification of the EEG, the question arises whether the EEG does at least stimulate innovation.[126]

A key indicator for a country's or a sector's innovative performance is the number of patent applications per year. Empirical studies based on this indicator do not paint a positive picture as regards the innovation effect of the demand-side promotion of renewable energies in Germany.[127]

According to an empirical study for the period between 1990 to 2005, electricity feed-in tariffs for renewable energy in Germany showed an innovation effect in the wind energy sector only.[128] A recent study which examined the technology-specific innovation effects of the EEG feed-in tariffs between 2000 and 2009 could not identify a positive correlation in any of the technologies.[129]

The EEG's fixed feed-in tariffs do not seem to provide incentives for developing new technologies. Since tariffs are based on average cost, the profits from a new technology innovation do not exceed those from an incumbent technology – despite the fact that investments in new technologies are associated with higher risk.[130]

The EEG primarily works as a demand-side subsidy for electricity from renewable energy sources and thus leads to a policy-induced expansion of markets for renewable energy technologies. For technology suppliers, this means that the pressure to innovate may decline: companies may have a stronger incentive to use their scarce resources for the exploitation of existing market potential rather than for engagement in R&D. Furthermore, a rapid expansion of more mature technologies, which leads to further cost reductions, may create market entry barriers for new technologies.[131]

Thus, also from an innovation policy perspective, the EEG in its current specification can be hardly justified. Precisely those renewable technologies that receive the bulk of EEG subsidies – i.e. photovoltaics, wind energy and biomass (cf. Table 1) – have failed to reveal significant positive innovation impacts to date.

Conclusion

In the view of the Expert Commission, the EEG is neither a cost-effective instrument for climate protection, nor does it exert a measurable innovation impact. Hence, for these two reasons, the continuation of the EEG cannot be justified.

B

B CORE TOPICS 2014

B 1 RESEARCH AND INNOVATION IN UNIVERSITY MEDICINE

B 1–1 ON THE IMPORTANCE OF MEDICAL RESEARCH

In recent decades, ground-breaking scientific discoveries in the fields of genetics and molecular diagnostics have generated waves of new developments and revolutionary changes in medical care. However, from the perspective of patients and doctors, medical research has also contributed to the development and dissemination of expensive medication and treatment methods. Life expectancy has risen over recent decades and an ageing population has increased the demand for healthcare services. At the same time, these developments have led to a strong increase in expenditure within the national health services worldwide, significantly exceeding economic growth in the respective countries. Table 2 shows the growth in healthcare expenditure for selected OECD countries for the period from 1970 to 2010. In Europe, it has nearly doubled from 4.9 percent to 9.6 percent as a share of GDP. This development also applies to Germany, France, the Netherlands and Switzerland, which currently spend 11 to 12 percent of their GDP on health. In the United States, the percentage of GDP expended on healthcare has increased from 7.1 percent to 17.6 percent in the same period.

In 2006, the Federal Government included the policy areas of health research and medical technology in its High-Tech Strategy, not least as a consequence of the social and financial importance of healthcare.[132] The new legislative period will also require important decisions to be made concerning the design of policy measures in these fields.

In recent decades, expenditure on medical research has increased even more strongly than that on healthcare. The United States has been in the vanguard of this development. Here, both the budget for basic biomedical research and the R&D expenditure of the pharmaceutical industry for biotechnology and medical technology have been increased considerably (cf. Table 3).

Between 1982 and 2012, US public and private R&D expenditure taken as a whole increased from USD 10 billion to USD 130 billion annually. The growth in the budget of the National Institutes of Health (NIH), the most important state organisation for biomedical research in the United States, was especially expansive. The annual funds of the NIH grew from USD 3.9 billion to USD 31 billion between 1980 and 2012 (with a GDP of USD 16.2 trillion).[133] Compared with the level of state funding in Germany, this represents a considerable difference. In total, Germany funded medical research to the tune of EUR 780 million in 2012 (with a GDP of EUR 2.7 trillion), of which EUR 287 million went to project management bodies within the German Aerospace Center (DLR) and EUR 493 million to the German Research Foundation (DFG).[134]

It is only in recent years that the United States' health research budget has been cut again due to limits on public funding resulting from increased healthcare and medical research costs. In Germany, health expenditure as a percentage of GDP has risen continually over recent years, however, it has not reached the US level.[135]

TAB 02

Development of healthcare expenditure as a proportion of GDP in selected countries 1970–2010

DATA DOWNLOAD

	National healthcare expenditure as a percentage of GDP				
	1970	1980	1990	2000	2010
Germany	6.3	8.4	8.3	10.4	11.5
France	5.7	7.0	8.4	10.1	11.7
Great Britain	4.5	5.6	5.8	7.0	9.6
Japan	4.6	6.4	5.8	7.6	9.6
Canada	7.0	7.0	8.9	8.8	11.4
Netherlands	7.2	7.4	8.0	8.0	12.1
Switzerland	5.4	7.2	8.0	9.9	10.9
USA	6.9	9.0	12.4	13.7	17.7
OECD	**5.3**	**6.6**	**6.9**	**7.8**	**9.6**

Source: own depiction based on OECD Health at a Glance 2013 (data for 1980 – 2010) and OECD Health at a Glance 2001 (data for 1970).

TAB 03

Development of R&D in the pharmaceutical industry in selected countries 1980–2010

DATA DOWNLOAD

	R&D expenditure in the pharmaceutical industry (in million USD PPP)				Growth p.a. 2000–2010	Percentage share of R&D expenditure in BERD
	1980	1990	2000	2010		
USA	1,777	6,287	12,793	49,415	14.5	17.7
Japan	742	2,647	4,811	11,351	9.0	10.6
Great Britain	496	2,003	4,475	6,945	4.5	28.6
Germany	528	1,263	2,315	4,609	7.1	8.0
France	322	1,179	2,557	3,762	3.9	11.9
Switzerland	–	–	991	2,988[4]	14.8	38.6
Belgium	–	238[1]	652	1,506[3]	9.7	11.6
Spain	–	192	355	1,002	10.9	9.6
Canada	–	204	621	549	–1.2	4.4
Denmark	–	144	610[2]	916	4.6	19.4

[1]1992 [2]2001 [3]2009 [4]2008
BERD: business enterprise expenditure on research and development
PPP: purchasing power parity
Source: own depiction based on OECD MSTI 2013/1 and OECD ANBERD 2009.

B 1–2 THE CENTRAL ROLE OF UNIVERSITY MEDICINE

University medicine is of central importance to the performance of medical research, as it is here that the link between healthcare provision and medical research is established. At the university hospitals both basic research and patient and hospital-related research is conducted, and thus the translation of research results into healthcare practice (see Box 3). In particular, clinical studies and initial trials are conducted at university hospitals. Furthermore, university hospitals are also responsible for the training of physicians and the training of young researchers. In recent years, research into rare diseases and their treatment, as well as the development of individualised medical treatment measures have gained in importance. Pharmaceuticals are being developed for ever smaller patient cohorts.

BOX 03 **Translation and translational medicine**

Basic scientific research is becoming increasingly important for clinical treatment. Translational medicine as a link between basic research (bench) and clinical application (bedside) is playing an increasingly important role. The key expression "from bench to bedside" defines the act of establishing a bridge between the knowledge of biological processes and new human diagnostic techniques and therapies. However, this does not simply imply a one-sided stimulation of clinical applications by basic research – it is equally the case that their implementation in patient-specific situations provides an important stimulus for basic research.

Yet, the process of translation within medical research is time and cost-intensive. Few insights gained in the laboratory are actually deployed in clinical praxis. In order to promote and expand translational research, it is also necessary to improve communication between researchers and physicians and feed knowledge gained from clinical applications back into laboratory research.

Over recent years, translational medicine has gained in importance and the focus of national research policies has increasingly shifted to the optimisation of translation processes.

Research in the university medicine sector increasingly calls for cooperation between various research disciplines. In particular, cooperation between medical professionals and scientists is becoming increasingly important. In order to guarantee the necessary interdisciplinarity, flexible forms of inter-institutional collaboration are of advantage. This presents university hospitals and their cooperation partners with new challenges.

B 1–3 INTERNATIONAL COMPARISON OF UNIVERSITY MEDICINE LOCATIONS

A comparison of the best performing university medicine locations from five countries strong in research – Germany, the Netherlands, Canada, Switzerland and the United States – has shown that Germany has competitive locations, however, none of them are ranked amongst the top locations internationally.[136] The United States have by far the best performing university medicine locations – defined as the respective universities together with the university hospitals and teaching hospitals, respectively (cf. Table 4). The US locations have the best publication performance and generate more patents than the research locations in the comparison countries.

These results are drawn from a study conducted by the Frauenhofer Institute for Systems and Innovation Research (ISI), commissioned by the Expert Commission. The goal of the study was to identify the strongest university medicine research locations worldwide and compare them with each other.[137]

Figure 11 shows the absolute number of publications per location as well as the publication intensity of the authors at the respective locations for 2012. Publication intensity is calculated by dividing the number of medical publications by the number of authors active at each location.[138]

The university medicine location with the highest level of publications is Boston/Cambridge with Harvard University and the associated university hospitals. The dominance of the Boston/Cambridge site is not just apparent in terms of absolute figures, but also in terms of publication intensity. The German sites, measured in terms of absolute number of publications as well as publication intensity, are generally ranked in the middle of the comparison group.

Overview of university medicine locations

TAB 04

DATA DOWNLOAD

Location	Institutions	Country
Berlin	Freie Universität Berlin, Humboldt Universität Berlin, Charité	DE
Hanover	Hannover Medical School, University Hospital	DE
Heidelberg	University of Heidelberg, University Hospital Heidelberg	DE
Munich	LMU Munich, TU München, University Hospital Munich	DE
Tübingen	University of Tübingen, University Hospital Tübingen	DE
Basel	University of Basel, University Hospital Basel	CH
Bern	University of Bern, University Hospital Bern	CH
Geneva	University of Geneva, University Hospital Geneva	CH
Zurich	University of Zurich, University Hospital Zurich	CH
Amsterdam	University of Amsterdam, Vrije Universität Amsterdam, University Hospital Amsterdam	NL
Leiden	University of Leiden, University Hospital Leiden	NL
Rotterdam	University of Rotterdam, University Hospital Rotterdam	NL
Utrecht	University of Utrecht, University Hospital Utrecht	NL
Hamilton	McMaster University, Hamilton Health Sciences - Chedoke McMaster Hospital	CA
Montreal	University of Montreal, McGill University, University of Montreal Hospital Centre, Montreal General Hospital	CA
Toronto	University of Toronto, University Health Network (Princess Margaret Cancer Centre, Toronto General Hospital, Toronto Western Hospital, Toronto Rehab)	CA
Vancouver	University of British Columbia, UBC Hospital	CA
Baltimore	Johns Hopkins University, Johns Hopkins Hospital	US
Boston/Cambridge	Harvard University, Massachusetts General Hospital - HMS (Harvard Medical School)	US
Houston	University of Texas, Houston, University of Texas Health Science Center at Houston	US
San Francisco	University of California, San Francisco, UCSF Medical Center	US
Washington	University of Washington, University of Washington Medical Center	US

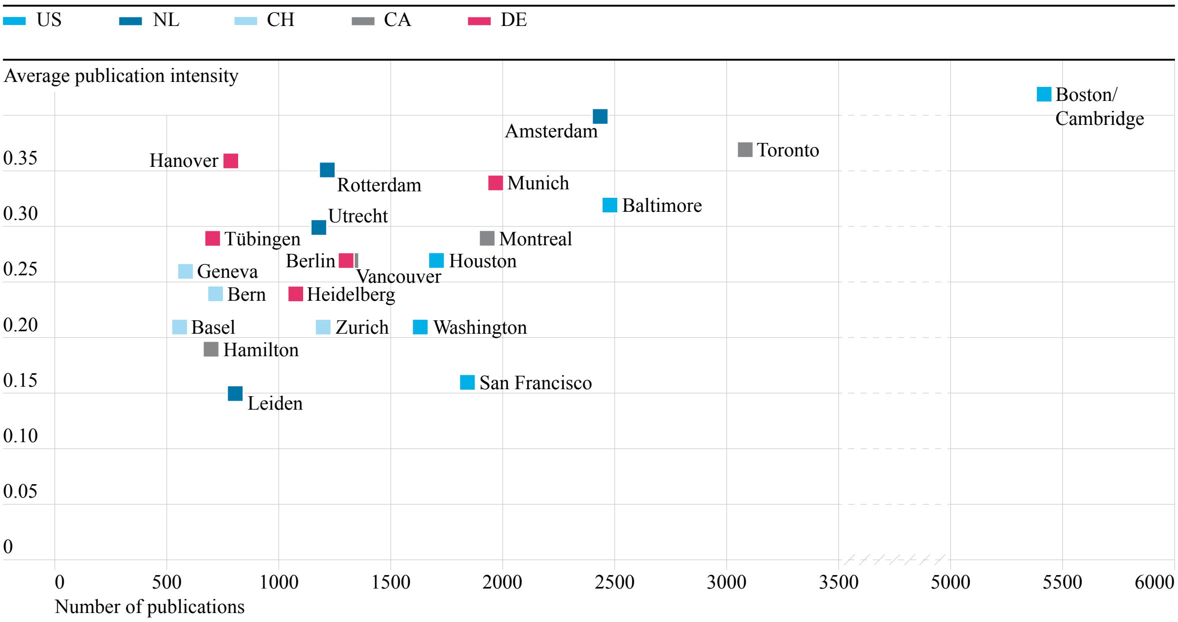
The above mentioned university medicine locations were selected on the basis of an analysis of the publication output. To distinguish between university publications and university hospital publications, the affiliations captured in the publications have been used. The publications of the affiliated university hospitals were captured as university hospital publications when the respective university was specifically included as an affiliate, or when the name of the respective city and the term "hospital" were mentioned as affiliates. For instance, publications of the Technical University of Munich's university hospital *Klinikum rechts der Isar* were assigned to the location of Munich when the respective publications mentioned the Technical University of Munich or the city of Munich under the author's affiliates.
Source: own depiction based on Frietsch et al. (2014)

This applies in particular to the locations of Heidelberg, Berlin and Tübingen. In terms of publication intensity, Munich and Hanover belong to the leading group. Although Munich exhibits a higher absolute number of publications than Hanover, Hanover has the highest publication intensity of all the German locations.

Figure 12 shows the excellence rate for the respective locations in 2010. The excellence rate is calculated as the percentage of a location's publications within the top 10 percent of cited medical research publications. This indicator is primarily designed to measure research excellence, i.e. the focus is on the quality of the publications from the respective locations. The highest excellence rates within the university medicine sector were achieved by US locations, above all Boston/Cambridge, followed by San Francisco and Houston. The only non-American location ranked in the leading group for this indicator was Rotterdam, followed by Baltimore and Washington. The German locations were generally ranked at

FIG 11 **Number of publications and publication intensity of locations in 2012**

DATA DOWNLOAD



Publication intensity: average number of publications per author.
Source: Web of Science, Scopus, calculations by Fraunhofer ISI.

How to read: in 2012, the authors active at the research institutions of the Boston/Cambridge location published 5,425 publications. On average this amounts to 0.42 publications per author (publication intensity).

the bottom of this comparison group. The exception here is Heidelberg, which achieved a middle ranking. Although quantitatively the Heidelberg site published less than the other German university medicine sites – both per capita and in total – it appears that Heidelberg had many publications of a higher quality compared with other German locations.

Overall, this indicator points to a highly country-specific picture. With a few exceptions, the highest excellence rates were achieved by the top locations in the United States, followed by the Netherlands, Canada, Switzerland and Germany. Yet, it should be noted that publications in US periodicals generally feature more frequently in the top 10 percent of cited publications worldwide, which, at least in part, accounts for the resulting ranking. It is probably still easier for authors from the United States to publish in a US periodical than it is for authors from other countries.

Figure 13 shows the number of transnational medical patent applications for the respective locations in relation to the average number of patent citations per application within the period 2005 to 2007. In addition to the quantity of applications, the qualitative dimension is also represented, measured in terms of the average number of patent citations within a three-year period. Patent citations are one of the most frequently used indicators for the quality of patents employed in academic literature.[139]

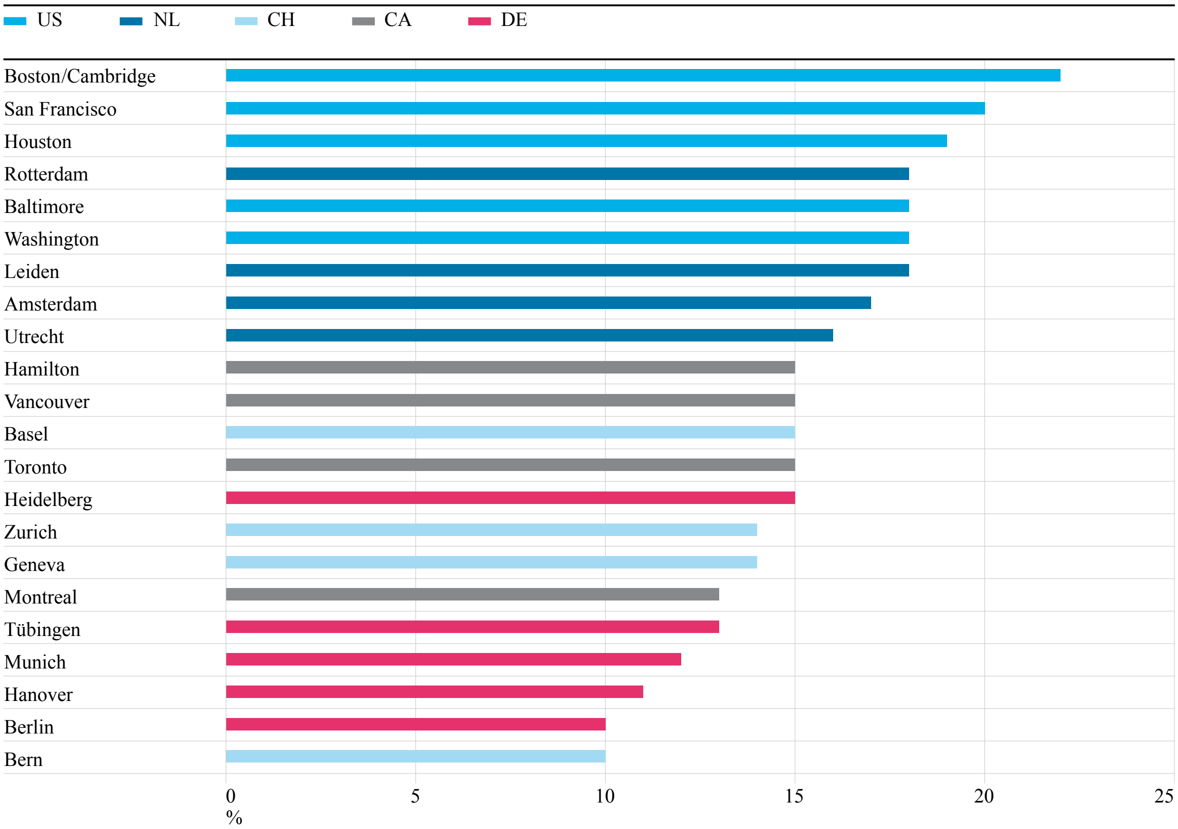
It is clear from the diagram that, on average, patent applications from the Utrecht location have a very high technological significance. The same applies to patent applications from the San Francisco, Washington and Harvard locations. The Swiss locations of Basel, Bern and Geneva also display very high values for this indicator. This is followed by a large middle field composed of locations from all countries with an average of 1.5 and two citations per patent application. German tertiary education institutions – led by Heidelberg – are situated in this middle field.

Figure 14 shows patent and publication intensity for the respective locations during the 2008 to 2010 period.[140] It is clear from the diagram that the Boston/Cambridge site not only occupies the top position with respect to the selected patent indicator,

Excellence rate of publications per location in 2010

FIG 12

DATA DOWNLOAD



Excellence rate: share of a location's publications that are among the top ten percent of the world's most frequently cited publications in medicine, relative to all medical publications of the respective location.
Source: Web of Science, calculations by Fraunhofer ISI.

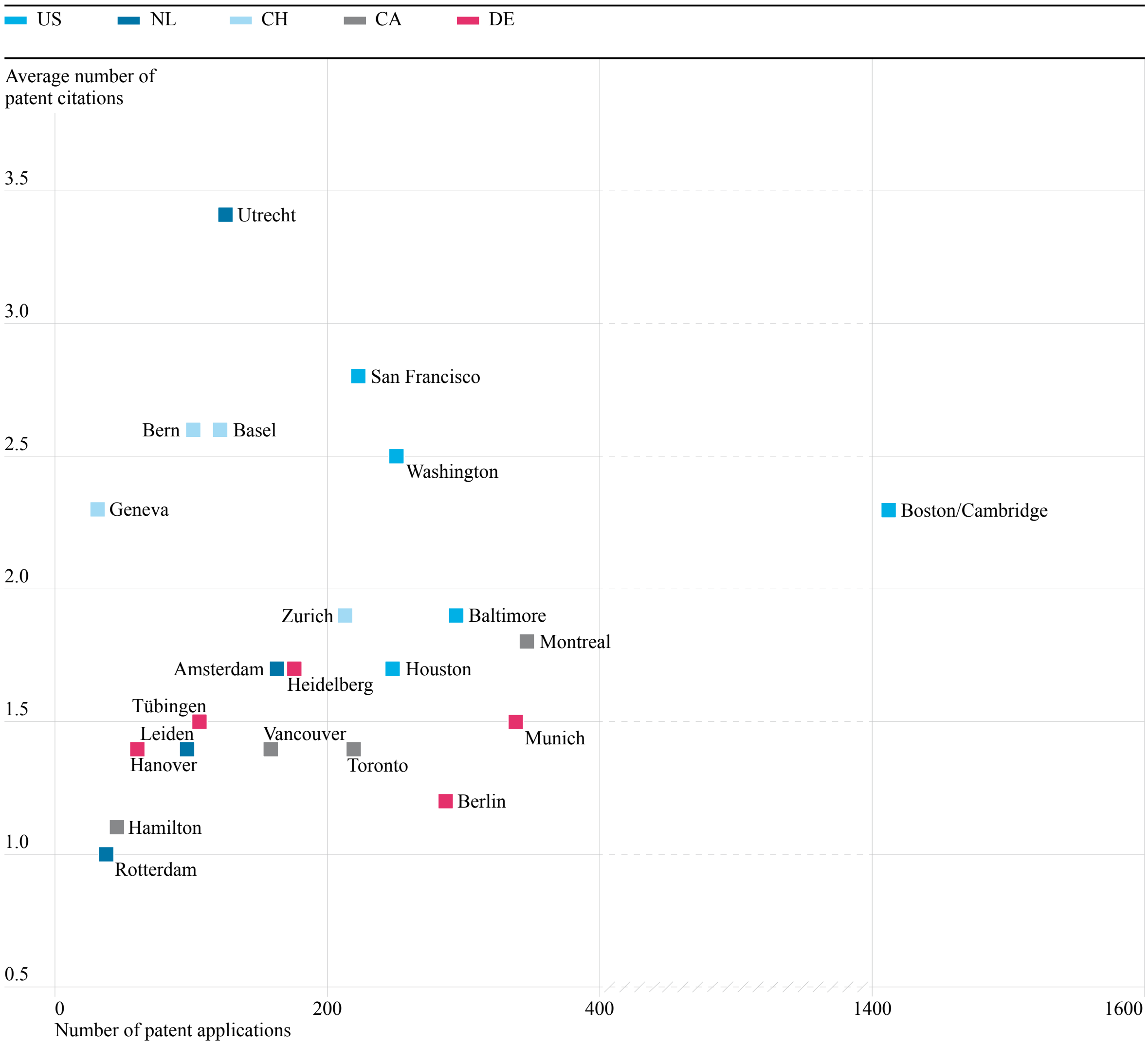
How to read: in 2010, 22 percent of medical publications published by authors active in the location of Boston/Cambridge were among the top ten percent of the world's most frequently cited medical publications.

but also displays the highest publication intensity by far. The Munich site displays a relatively high patent and publication intensity, being ranked third for patents and fourth for publications within the comparison group. The Basel, Bern, Berlin, Heidelberg and Baltimore sites also demonstrate a relatively high patent intensity. However, they tend to be ranked in the middle field in terms of publications. Overall, it is clear that the respective locations have diverse profiles, pursuing both scientific publications and patent applications as opposed to concentrating exclusively on the one or the other.

The comparative study documents the dominance of the Boston/Cambridge site with Harvard University and the associated hospitals in the field of biomedical research. The Boston/Cambridge site not only produces more biomedical publications and patents than all the other locations worldwide, it is also the leader in terms of the quality of results and the productivity of the researchers and inventors. German locations are ranked in the middle field in terms of patents and publications as well as productivity. German locations score less well in terms of research quality measured according to the publication excellence rate. A further improvement in scientific performance should therefore be primarily focussed on the quality of these research contributions.

FIG 13 **Number of transnational medical patent applications and average number of patent citations per application 2005–2007**

DATA DOWNLOAD



Source: EPA - PATSTAT, calculations by Fraunhofer ISI.

How to read: between 2005 and 2007, 1417 transnational medical patents were filed by scientists active at the location of Boston/Cambridge. On average, each of these filed patents was cited by subsequent patents 2.3 times within a period of four years.

B 1–4 ORGANISATIONAL FRAMEWORK OF MEDICAL RESEARCH

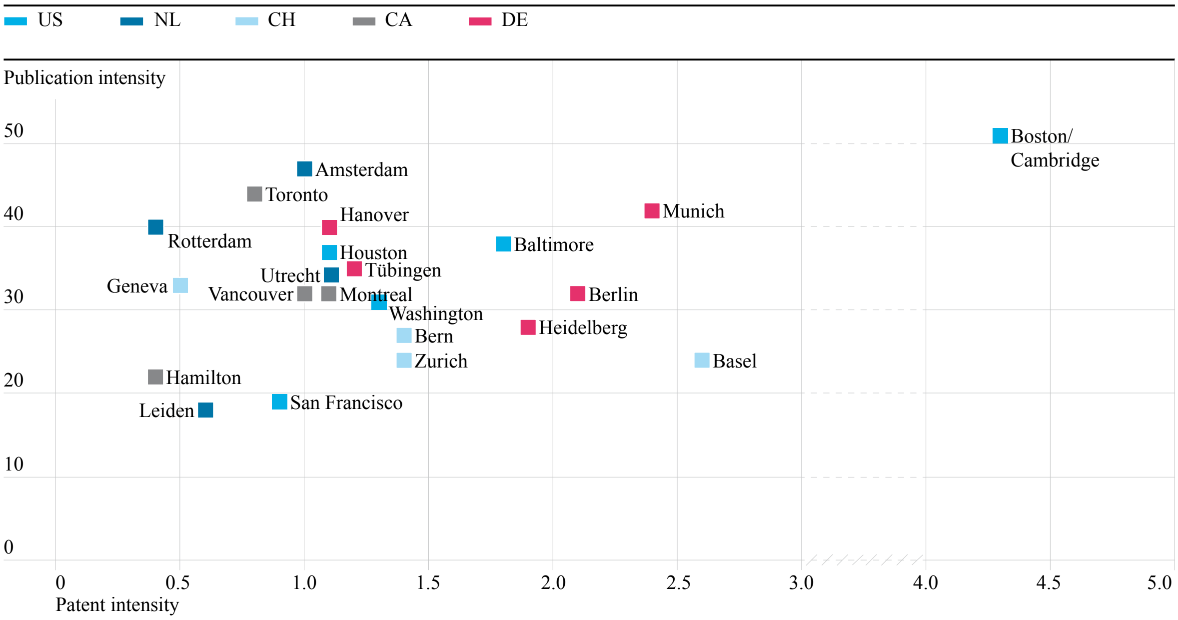
The funding of medical research is organised differently internationally

The funding of medical research in Germany, as in other countries, is characterised by institutional complexity. The following comparison of the funding structures in Germany, Canada, the Netherlands, Switzerland and the United States provides an overview of the most important institutions for the financing of medical research as well as the institutions which conduct medical research. Current changes in the funding structure in Germany are analysed against this background. While funding in the United States, Canada and the Netherlands is primarily administered by independent institutions which in some cases are explicitly responsible for medical research, in Germany public funds are awarded by administrative organisations that do not have any specific medical focus. These intermediary organisations are the

Patent and publication intensity of locations 2008 – 2010

FIG 14

DATA DOWNLOAD



Patent and publication intensity: number of transnational patent applications/publications per 100 authors.
Source: Web of Science, Scopus, EPA - PATSTAT, calculations by Fraunhofer ISI.

How to read: between 2008 and 2010, an average of 51 publications and 4.3 patent applications per 100 publishing scientists (authors) was recorded for the location of Boston/Cambridge.

German Aerospace Center (DLR), which as project management body administers the awarding and co-ordination of research funds on behalf of the Federal Ministry of Education and Research (BMBF), and the independent German Research Foundation (DFG) financed by the Federal and *Länder* governments.

In the comparison countries the institutions responsible for medical research, such as the National Institutes of Health (NIH) in the United States or the Canadian Institutes of Health (CIHR), are under the auspices of the respective health ministries. While these ministries function as funding bodies, they delegate the execution of this task to the responsible funding institutions, which are frequently also responsible for strategy development and the implementation of coordinated, topical funding in the field of medical research.[141]

In Switzerland, public research funding is the responsibility of the Swiss National Science Foundation (SNF), which acts on behalf of the federal government. The national foundation awards funding for the medicine/biology sector but does not undertake any research activities itself.[142]

An essential feature of the German research system is the separation between funding and research institutions. The DLR, which operates at the behest of the BMBF and the BMG, and the DFG, operate as funding bodies but do not conduct any R&D activities themselves. This institutional separation is justified on the grounds that it helps to prevent conflicting goals in the perceived role of the scientific establishments. The DFG is concerned that equitable cooperation between different research facilities would be made more difficult if one of the cooperation partners had to apply to the other for the funding required for the cooperation.[143]

The separation between funding and research institutions established in Germany does not exist in the United States or Canada, or in the basic research sector in the Netherlands.[144] In the United States, the NIH also carries out its own research. In 2012 the NIH invested around USD 5.7 billion of its total budget in its own research projects; the vast majority, to the sum of USD 25 billion, was awarded to projects outside the NIH. While the CIHR in Canada and the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO)[145] are primarily responsible

BOX 04

Boston/Cambridge as a centre of life sciences and innovation

The Boston/Cambridge region, like no other location worldwide, displays excellent framework conditions for successful medical research. With more than 100 universities and colleges, Boston/Cambridge is the intellectual stronghold of the east coast. It has ca. 4.5 million inhabitants and in 2012 generated an economic output of almost USD 340 billion.[146] In addition to the top universities of Harvard and the Massachusetts Institute of Technology (MIT) in its immediate proximity, the region of Boston/Cambridge is also home to further renowned private universities (Boston University, Northeastern, Tufts, Boston College, Brandeis University, etc.) and state universities, such as the University of Massachusetts. The academic landscape of the Boston/Cambridge region is enhanced by the renowned teaching hospitals of the Harvard Medical School and Boston University (Beth Israel Deaconess Medical Center, Brigham and Women's, Children's, Massachusetts General Hospital), which for years have occupied a pole position with respect to research funding from the National Institutes of Health (NIH). In addition, the Boston/Cambridge region is also home to highly renowned research institutes such as the Whitehead Institute, the Broad Institute, jointly run by Harvard University and MIT, the Dana-Farber Cancer Institute, belonging to Harvard Medical School, and the David H. Koch Institute for Integrative Cancer Research. A further important research institute is the Draper Laboratory, which mostly conducts research work commissioned by the Ministry of Defense.

In addition to the extraordinary density of universities, hospitals and research facilities, nine out of ten of the world's largest companies from the biotechnology and pharmaceutical industries have a presence in Boston, including the global research centres of Novartis, Merck and AstraZeneca. The origins of the formerly venture capital-backed companies such as Biogen Idec and Genzyme (Sanofi) are also found here. Furthermore, the corporate side, in particular the transfer of research findings into new products, is strengthened by the presence of numerous venture capitalists.

A focus of these Boston-based institutions is translational medicine, i.e. the rapid implementation of scientific knowledge in clinical practice.[147] The close cooperation required for this is made considerably easier by their immediate proximity to one another. Many of the institutions named are in fact within walking distance of each other.[148]

The research institutions located in Boston/Cambridge are continually experimenting with new forms of cooperation. In the field of cancer research for instance, the David H. Koch Institute provides an institutional framework for the interdisciplinary cooperation of engineers and biologists with MIT scientists from different specialties. This cross-disciplinary approach is also the focus of the "Bridge Project" initiated by the Koch Institute and the Dana-Farber Cancer Institute. The aim is for teams composed of scientists from different specialties to think beyond traditional scientific networks and thus identify new paths for cancer research.

A similar interdisciplinary approach is also pursued by the Broad Institute. Formally connected to the MIT, Harvard University and the associated hospitals, the Broad Institute links the work of students, postgraduates, scientists and administrative specialists in its own research projects. The institute's three organisational units (core member laboratories, programs and platforms) are characterised by a regular interdisciplinary exchange and the bundling of cross-disciplinary expertise.

for the awarding of funding to external research institutions, they can also conduct their own research projects at the affiliated institutes.[149]

A similar approach was first adopted in Germany with the establishment of the German Centres for Health Research (DZG) in 2009. Thus, the Helmholtz institutes integrated into the DZG are entrusted with research tasks as well as assuming responsibility for administering funds for the other participating research institutes.[150] However, in distinction to the institutions named above, the focus of the Helmholtz Association (HGF) is the conduction of its own research. In terms of volume, the administration

Boston/Cambridge and its major medical research institutions FIG 15

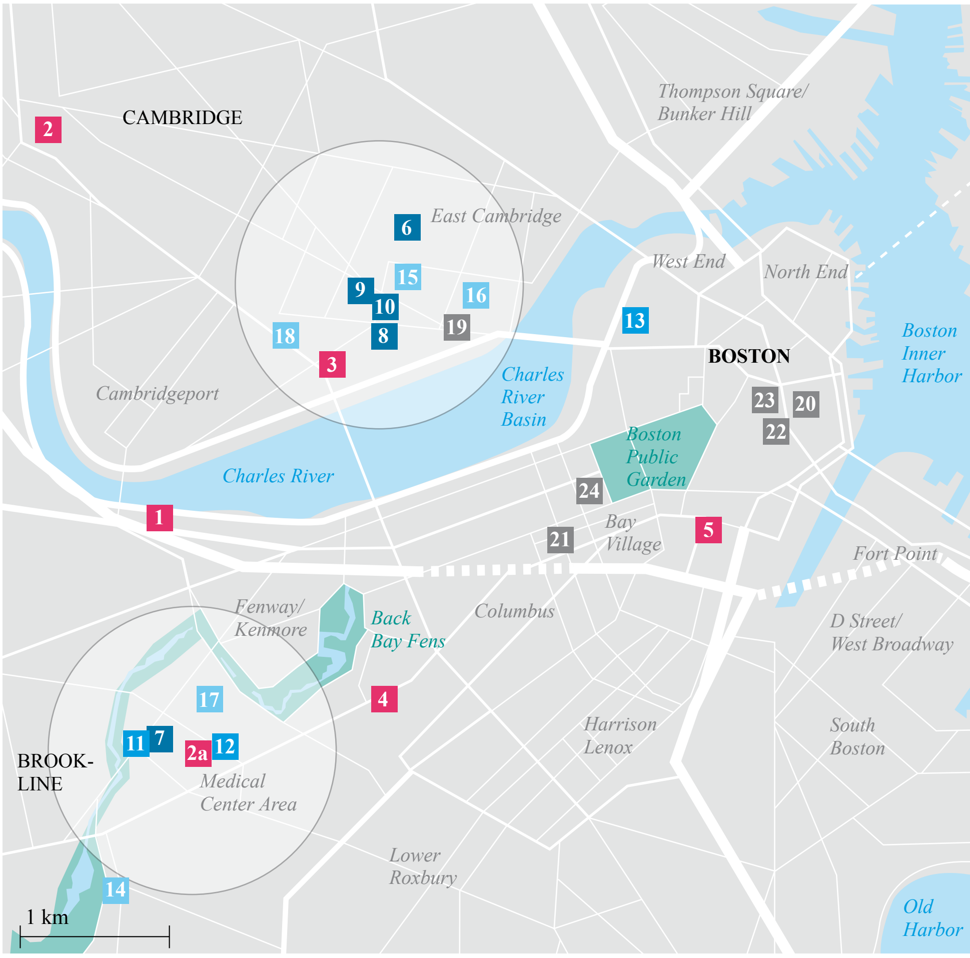
Universities
- 1 Boston University
- 2 Harvard University
- 2a Harvard Medical School
- 3 Massachusetts Institute of Technology
- 4 Northeastern University
- 5 Tufts University School of Medicine

Research institutes
- 6 Broad Institute
- 7 Dana-Farber Cancer Institute
- 8 David H. Koch Institute for Integrative Research
- 9 Draper Laboratory
- 10 Whitehead Institute for Biomedical Research

Teaching hospitals
- 11 Beth Israel Deaconess Medical Center
- 12 Brigham & Women´s Hospital
- 13 Massachusetts General Hospital

Companies
- 14 AstraZeneca Hope Lodge Center
- 15 Biogen Idec
- 16 Genzyme Corporation
- 17 Merck Research Laboratories
- 18 Novartis Institutes for Biomedical Research

Venture capitalists[151]
- 19 Clarus Ventures
- 20 Morgenthaler Ventures
- 21 MPM Capital
- 22 Needham Funds
- 23 Schroder Ventures Life Sciences
- 24 Third Rock Ventures



Source: own research.

of external projects only constitutes a small part of its work.

In addition, measures have been taken to limit potential conflict between the tasks of research and research funding. Thus, during the establishment of the DZG the Helmholtz institutes were not involved in the process of selecting the other facilities. The selection of all the facilities incorporated in the DZG was carried out by the BMBF and the DLR in collaboration with an external evaluation committee. In the opinion of the Expert Commission, these measures have initially succeeded in preventing the feared conflict of interest.

However, in its position paper “Helmholtz 2020 – Shaping the Future Through Partnership”, the HGF suggests that institutional funding should be more closely linked to project funding, proposing the conduction of its own project funding activities as a means to achieve this.[152] The Expert Commission rejects this idea (cf. Chapter A 1), as a mandate extended in this fashion would upset the well-balanced division of roles established between non-university research organisations and the universities, to the detriment of the universities.

The different funding practices of the German funding institutes DFG and DLR

With the DFG and the project management organisation DLR, working at the behest of the BMBF and the BMG, Germany has established a complementary structure for research funding that is unique worldwide. However, the funding practices of the two institutions display a number of distinct features. While the BMBF/DLR conducts programme-oriented research funding organised according to strategic goals (top-down), the DFG primarily funds basic research in which the researchers themselves select the research topic (bottom-up).

Funding from the BMBF/DLR is often described by universities and non-university research organisations as more bureaucratic than that from the DFG. In many cases, funding by the BMBF/DLR is associated with more complex research specifications and more elaborate controlling procedures.[153]

While there may be objective reasons for the increased administrative requirements,[154] the Expert Commission calls for the identification of any tendencies towards excessively bureaucratic handling of funding instruments by the funding organisations, and their limitation.

Furthermore, researchers active in the university medicine sector complain that in the case of BMBF/DLR financed research projects – in contrast to DFG financed projects – it is difficult to meet the requirements with respect to a clear division between research activities and patient care. In principle the DFG, just like the BMBF/DLR, also demands that research and patient care times be listed separately. That said, the practical implementation of these requirements is considered to be less strict and comparatively unbureaucratic with DFG projects.[155]

Promoting translation through new forms of cooperation

To improve the translation of results, university hospitals collaborate with private enterprises and non-university research organisations.[156] Forms of cooperation extend from cooperation on individual research projects, institutional cooperation in larger funding contexts – such as special research fields, the excellence initiatives and the German Centres for Health Research – through to the partial fusion of the participating institutions. Thus, from 2015 onwards, cooperation between the Charité and the Max Delbrück Center for Molecular Medicine (MDC) will be conducted within the framework of the newly founded Berlin Institute of Health (BIH), a public corporation.[157]

The six German Centres for Health Research currently form a framework for cooperation between university medicine and non-university research organisations. These centres are designed to offer optimal conditions for research into major widespread diseases in Germany, while also promoting cross-institutional cooperation in health research. Thanks to their integrative structure, they help to network researchers from universities and non-university research organisations working in the field of major widespread diseases. This networking and the associated expansion of existing research structures for translational research, together with the close interaction

TAB 05

DATA DOWNLOAD

German Centres for Health Research (DZG)

Name of centre	Year established	Number of locations	Organisations-form	Administrative office	Fund administration
German Center for Cardiovascular Research (DZHK)	2010	7	registered society	Autonomous (Charité)	Max Delbrück Center for Molecular Medicine (Helmholtz)
German Center for Infection Research (DZIF)	2010	7	registered society	Helmholtz Centre for Infection Research	Helmholtz Centre for Infection Research
German Center for Lung Research (DZL)	2010	5	registered society	University of Giessen (University Hospital Giessen and Marburg Lung Center, UGMLC)	Helmholtz Zentrum München
German Consortium for Translational Cancer Research (DKTK)	2012	8	foundation	German Cancer Research Center (DZKF) Heidelberg (Helmholtz)	German Cancer Research Center (DZKF) Heidelberg (Helmholtz)
German Center for Diabetes Research (DZD)	2009	5	registered society	Helmholtz Zentrum München	Helmholtz Zentrum München
German Center for Neurodegenerative Diseases (DZNE)	2009	9	Helmholtz Centre + cooperation partners (registered society)	DZNE location Bonn (Helmholtz)	DZNE location Bonn (Helmholtz)

Source: Loos et al. (2014: 168).

with the corporate sector, are designed to facilitate a more rapid transfer of research results into everyday clinical practice.[158]

In the period up to 2015, the six centres that have been established since 2009 will receive BMBF funding totalling EUR 700 million. The Federal Government provides 90 percent of the funding, while the remaining 10 percent come from the federal states participating in the DZG.[159]

Even though the DZG have chosen different organisational forms and different cooperation structures, a feature they all share is the management of funds by the participating Helmholtz centres. Four of the DZG have also located their administration offices in a Helmholtz centre. The prominent role of the Helmholtz Association relative to the university partners has been widely criticised.[160] The Federal Government justifies the central role of the Helmholtz centres with the argument that their specific mission and funding structure enables them to guarantee the sustainable development of the DZG.[161] According to the coalition agreement, the concept of the German Centres for Health Research is to be pursued within a science-led process.[162] Whether the role of the Hemholtz Association will be further strengthened in this process remains to be seen.

Initial experiences with the centres have shown the extent of the development and coordination work required, e.g. in respect of the use of data and proprietary rights, before research projects can be reliably conducted. Since the professional evaluation of the centres is scheduled to begin in 2014, it is not currently possible to assess which of the DZG have successfully negotiated the initial phase, which organisational forms have proven most effective, and whether the overall model can be considered a success.[163] The decision on the future structure and organisation of the centres, as well as the establishment of further centres, will be dependent on the results of the evaluation.

B 1–5 THE FINANCING OF R&D IN THE UNIVERSITY MEDICINE SECTOR

Germany ranked in the middle field for public funding of health-related R&D

The international comparison of state funding for R&D in the health sector is based on data from the OECD (cf. Figure 16).[164] In 2012, health-related R&D in Germany was funded to the tune of EUR 4 billion,[165] equivalent to 0.15 percent of GDP. In the United States and the Netherlands, health-related R&D was funded more intensely (0.23 and 0.20 percent of GDP, respectively). As the corresponding rates for Canada and Switzerland are not available, these countries cannot be included in the analysis. A comparison with further countries shows that state funding for health-related R&D in Germany is in the middle field.[166]

FIG 16

Government funding for health-related R&D (2012) as a percentage of GDP

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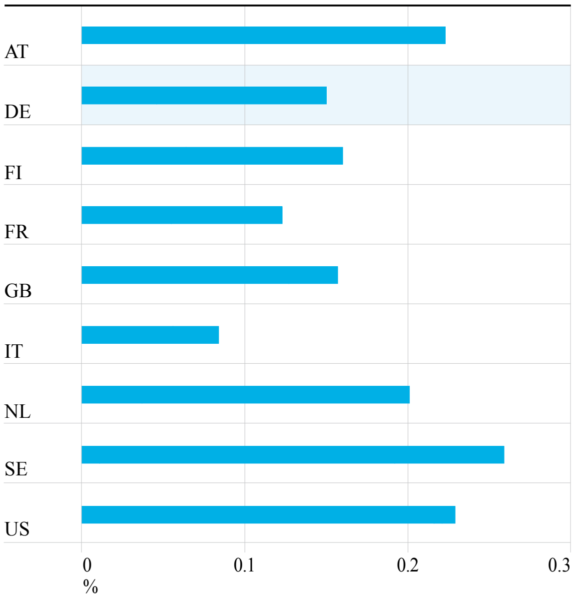

Source: OECD Science, Technology and Industry Scoreboard 2013. Figures on Finland, Great Britain, Italy and Sweden refer to 2011.

Income from healthcare is decisive in determining the budget of German university medicine

The duties of Germany's university medicine sector – consisting of healthcare, research and teaching – are financed from three sources: administrative income (primarily from healthcare provision), basic funds and third-party funding (cf. Figure 17).

– The universities' administrative income is largely composed of revenue from economic activities and assets.[167] In Germany's university hospitals, administrative income from healthcare provision contributes the lion's share to the financing of university medicine. Since 2004, hospitals bill their services according to the integrated, performance-related and flat rate DRG remuneration system (Diagnosis Related Groups remuneration system).[168] Over recent years, the administrative income in the university medicine sector has risen continuously – from EUR 8.8 billion in 2002 to EUR 13.4 billion in 2011.[169] This represents an annual growth rate of 4.8 percent.
– Basic funds in the university medicine sector have increased from EUR 4.3 billion in 2002 to EUR 5.0 billion in 2011.[170] This represents an average annual growth rate of 1.9 percent for this period.
– Third-party funding is composed of revenue raised by the universities in addition to their regular budget. It is almost exclusively used for the financing of research. In 2011, the universities succeeded in raising a total of EUR 1.53 billion in third-party funds in the areas of human medicine and health sciences.[171] Third-party funding has risen continuously at an average rate of 6.6 percent per annum since 2002.

The university medicine budget continues to be largely determined by administrative income. While the percentage of basic funds in the period under consideration fell from 30.6 to 25.3 percent, the percentage of administrative income rose from 63.2 to 67.1 percent.

In 2011, just under EUR 3.45 billion was spent on research and development in the field of medicine/health sciences.[172] That represents 26 percent of the total R&D expenditure at universities (EUR 13.34 billion). Compared with 2002, R&D expenditure in the university medicine sector has risen by 51 percent, i.e. an average of 4.7 percent per annum. This is somewhat higher than the growth in the other fields combined (49 percent, i.e. an average of 4.5 percent per annum).

Basic funds, administrative revenue and third-party funds in university medicine 2002–2011

FIG 17

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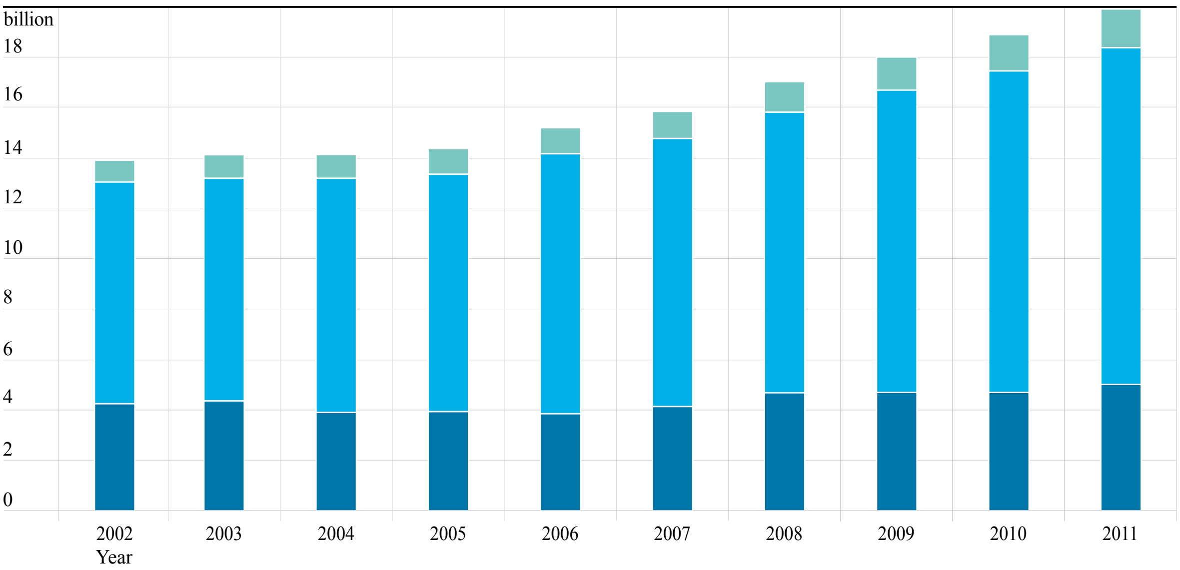


Source: *Statistisches Bundesamt, Fachserie 11, Reihe 4.5.* Values refer to the human medicine/healthcare sciences subjects group.

University hospitals with systematic additional expenses

Despite the significant increase in income from healthcare provision, a substantial percentage of German university hospitals are faced with funding deficits. In summer 2013 the University Chancellors' Working Group on University Medicine *(Kanzlerarbeitskreis Hochschulmedizin)* predicted that just under half of the university hospitals would have a negative annual result for 2013 and that only 20 percent of the clinics would be in the black.[173] As a consequence, a number of stakeholders, including the Association of University Hospitals in Germany (VUD) and the Medical Faculty Association (MFT) call for financial compensation for the additional costs faced by university hospitals for which the DRG remuneration system does not offer any, or sufficient, financial compensation. It is argued[174] that the university hospitals are subject to above-average financial pressures, e.g. as a result of a relatively high percentage of extreme cost cases that are not adequately covered by the DRG system, insufficient funding of the university outpatient departments, the absence of performance-related and timely financing of new examination and treatment methods as well as a high percentage of physicians undergoing further training.

To the extent that the university medicine sector is faced with unremunerated costs, there is a danger that loss-making healthcare provision in the university hospitals will be subsidised by funds that are actually meant for research and teaching. Thus, in the past cost shifting has been criticised,[175] according to which, as a consequence of poor transparency, there is no guarantee that funds earmarked for research and teaching at the university hospitals are exclusively used for this purpose. Instead, the existing framework conditions and incentives would tend to suggest that loss-making healthcare provision is being subsidised. According to the University Chancellors' Working Group on University Medicine, the "close financial links between clinic and faculty result in the diversion of funds designated for research and teaching to the offsetting of losses from healthcare provision."[176] In the view of the Expert Commission, it is correct that research resources within this context are not always used for their intended purpose.

In other countries, systematic additional expenses faced by the university hospitals resulting from research or training are frequently taken into account – as is the case in Canada, the Netherlands, Switzerland

and the United States.[177] Furthermore, in the US, there is additional remuneration for high cost cases:

- In Canada the provincial health ministries award the Academic Health Science Centres (AHSC) a subsidy for research and training.
- In the Netherlands the university hospitals (UMC) receive additional funding for their special role in research, training and innovation – the so-called "academic component" for research, financed by the ministry of health. The UMC also receive a contribution from the education ministry for training and research.
- In Switzerland hospitals are paid an additional pro-capita flat rate for the further training of physicians. As a matter of principle, these flat rate payments are higher for university clinics; however, they are also awarded to non-university hospitals where training is conducted.
- In the Unites States additional expenses are not compensated for directly. However, hospitals can receive additional operational funding to cover indirect costs resulting from the further training of medical specialists (Indirect Medical Education Index), the direct costs of the training of assistant doctors (Direct Graduate Medical Education) and the treatment of Medicare and Medicaid patients. Furthermore, additional remuneration for high cost cases is also provided. University hospitals benefit from these supplementary financing regulations to a high degree.

The coalition agreement between CDU, CSU and SPD addresses this problem in Germany.[178] Accordingly, remuneration of the special duties of university hospitals and maximum care hospitals within the DRG system is to be improved. The Institute for the Hospital Remuneration System (InEK) has been commissioned to develop a suitable special remuneration system by the end of 2014 for high cost cases that cannot be properly accounted for within the flat rate per case system. Furthermore, the services of the university outpatient departments are to be adequately remunerated in future.

The VUD and the Academic Advisory Board of the German Medical Association estimate the funds required to meet the systematic additional expenses incurred by university hospitals at around EUR 1 billion per annum.[179] The National Association of Statutory Health Insurance Funds *(GKV-Spitzenverband)* refers to the InEK analysis due at the end of 2014, which will indicate where cost deficits as well as cost surpluses have been incurred.[180]

The MFT and VUD are doubtful whether a change to the DRG system alone will be sufficient to completely offset the systematic additional costs incurred by university hospitals at the required speed.[181] Together with the German Society for Internal Medicine (DGIM) and the University Chancellors' Working Group on University Medicine, they see the need to introduce a system subsidy as an independent source of financing for the university medicine sector.[182] In the opinion of the VUD, both the statutory health insurance funds and the BMBF could be considered as potential financiers, as important additional costs have a clear relationship to either healthcare provision or research.[183] In contrast, the German Medical Association considers specific additional payments linked to concrete performance parameters to be superior to flat rate system subsidies.[184] For example, a fictive standard subsidy for research and teaching per student, or a system modeled on other student performance figures and third-party funding procurement would be expedient.

The Expert Commission acknowledges that the university medicine sector is subject to additional expenses for which there is at least partial compensation in all the comparison countries examined, with the exception of Germany. As a result, research at German university hospitals is at a disadvantage relative to comparable institutions abroad. There is also the danger of systematic cross-subsidisation of healthcare provision using research funds.[185] The Expert Commission thus welcomes the fact that the governing parties have addressed the problem of additional expenses in their coalition agreement.

B 1–6 CLINICAL STUDIES

The situation of clinical studies in Germany has improved

Clinical studies play a prominent role in the translation of the results of basic research into patient care. They are compiled with the participation of patients, i.e. test persons. A distinction is to be made between clinical trials and observational studies.[186] In the case of clinical studies, participants receive a specific treatment that is carried out according to a study plan. The goal could be e.g. to test the safety or efficacy of medication or medical devices. In the case of observational studies, no specific (additional) treatment is specified on the part of researchers. Instead, the aim is the systematic collection of data on specific patient or population groups.

Patient-oriented clinical research did not become the focus of medical research in Germany until well into the 1990s.[187] In 2003, the BMBF and the DFG introduced continual funding of clinical studies as part of a joint initiative.[188] In recent years, the BMBF has carried out increased structural funding measures as a complement to project funding with the goal of improving the framework conditions for patient-oriented clinical research in Germany (cf. Box 5). According to existing evaluations of these structural funding measures, they successfully complement the

BOX 05

BMBF structural support measures to improve framework conditions for patient-oriented clinical research[189]

- Coordinating Centres for Clinical Trials (KKS):[190] The KKS are designed to support all the processes involved in clinical trials. They play the role of a central service organisation for the universities, providing personnel and logistical resources for the planning, implementation and evaluation of clinical trials. The BMBF financed the creation of twelve KKS between 1999 and 2009 with a total of EUR 38 million. Furthermore, within the framework of the BMBF's public announcement "Coordinating Centres for Clinical Trials", the Pediatric Network for the development and testing of pharmaceuticals for children and young people within the KKS (PAED-Net), the Study Network Surgery (CHIR-Net) and the German Clinical Trials Register (DRKS) have been or will be supported.[191]
- Clinical Study Centres:[192] The Clinical Study Centres are designed to coordinate patient-oriented clinical research at the university hospitals. Furthermore, they are designed to train study personnel and young scientists. In a first round of funding from 2007 to 2011, the BMBF financed Clinical Study Centres at six sites to the tune of around EUR 24 million. Funding will continue in a second round ending in 2015 with EUR 20 million being awarded to five sites. The sites will be equipped with the necessary resources, study know-how will be developed and the recruitment potential of the hospitals, i.e. their regions, will be ascertained.
- Integrated Research and Treatment Centers (IFB):[193] In the period from 2006 to 2015, several centres are being established with the help of IFB funding. Each of the centres will specialise in one important disease area and encompass both research and treatment, and contribute towards strengthening the profile of the respective medical faculties and their university hospitals. The funded universities are to develop suitable, cross-disciplinary structures in order to increase the attractiveness of patient-oriented research and to improve support for young researchers. Up to now eight IFB concepts have been funded to a total of EUR 148 million.
- Competence Networks in Medicine:[194] Since 1999, the BMBF has funded a total of 21 Competence Networks in Medicine covering a range of different diseases. Horizontal networking is designed to facilitate interdisciplinary cooperation between hospitals and basic research; vertical networking is designed to promote the integration of all levels of research and patient care as a means to accelerate knowledge transfer. With the conduction of multi-centric therapy studies within the networks progress in clinical research is to be achieved. In the period between 1999 and 2007 a total of around EUR 225 million was awarded to 17 competence networks. Around EUR 250 million is currently earmarked for the funding of competence networks over a twelve-year period.

project funding of clinical studies through the creation of an infrastructure.

According to the evaluation of the Coordinating Centres for Clinical Trials (KKS) and the Clinical Study Centres, these funding measures have succeeded in establishing structures for patient-oriented clinical research which continue to function after the funding from the BMBF has ended.[195] The structures offer a broad palette of advisory and consultation services, thus functioning as full-service organisations for the planning and implementation of clinical studies. Thus, according to the evaluation, they have assumed an important local role in many clinical trials and have had a positive influence on their quality. Thanks to their training and further training offers, they have had a positive effect extending beyond the centres themselves, improving the competences of participants in respect of the planning and implementation of clinical studies. At many sites, the KKS structures have led to a more professional cooperation between university medicine and the pharmaceutical industry. However, the evaluation also concluded that the funded centres were less successful in achieving the goal of influencing the faculties and clinics in order to bring about changes and improvements in the framework conditions for research. In addition, there were acceptance problems on the part of the clinicians at a number of sites. The financing situation of the centres is problematic: in many cases the institutions have succeeded in procuring more third-party funds following the end of the BMBF funding and a reduced or constant level of financing from federal state funds. However, this was frequently accompanied by a greater focus on studies financed by industry as well as a reduction in the range of services offered.

The evaluation of the Competence Networks in Medicine[196] attributes a strengthening of non-commercial medical research in Germany to the support measures. The competence networks facilitate the recruitment of patient samples of a sufficient size and multicentric approaches for the generation of valid and evidence-based results.[197]

High number of clinical trials in Germany

ClinicalTrials.gov – a service provided by the NIH – has recorded around 156,000 clinical trials worldwide. Around three quarters of these trials were conducted in North America and Europe (cf. Figure 18). A quarter of the ca. 44,000 European trials were conducted with German participation (cf. Figure 19).

According to a survey among experts from industry, academic clinical trial units and clinical research organisations, Germany, Great Britain and the Netherlands are considered the best locations for clinical trials in Europe.[198]

However, there are hardly any international comparative figures for the costs to pharmaceutical companies of conducting clinical trials. A report financed by the NIH published in 2010 states that clinical trials conducted in Germany are only half as expensive as studies conducted in the United States.[199] The comparison countries Canada, the Netherlands and Switzerland were not included in the evaluation. According to an earlier study from Charles River Associates,[200] which provided an international comparison of the average costs per patient for phase III trials, those conducted in Germany were well below those in the United States and Canada and at a similar level to those in the Netherlands.

Adequate structures required for clinical research in the field of rare diseases

The causes of many rare diseases (RD) (cf. Box 6) have not been investigated yet. Establishing their causes is not only of importance for the treatment of patients with RD; it can also contribute to an understanding of fundamental biomedical relationships and thus of common diseases.[201] The reason for this is that RD can generally be traced back to a few individual factors which can be intensively and extensively researched.

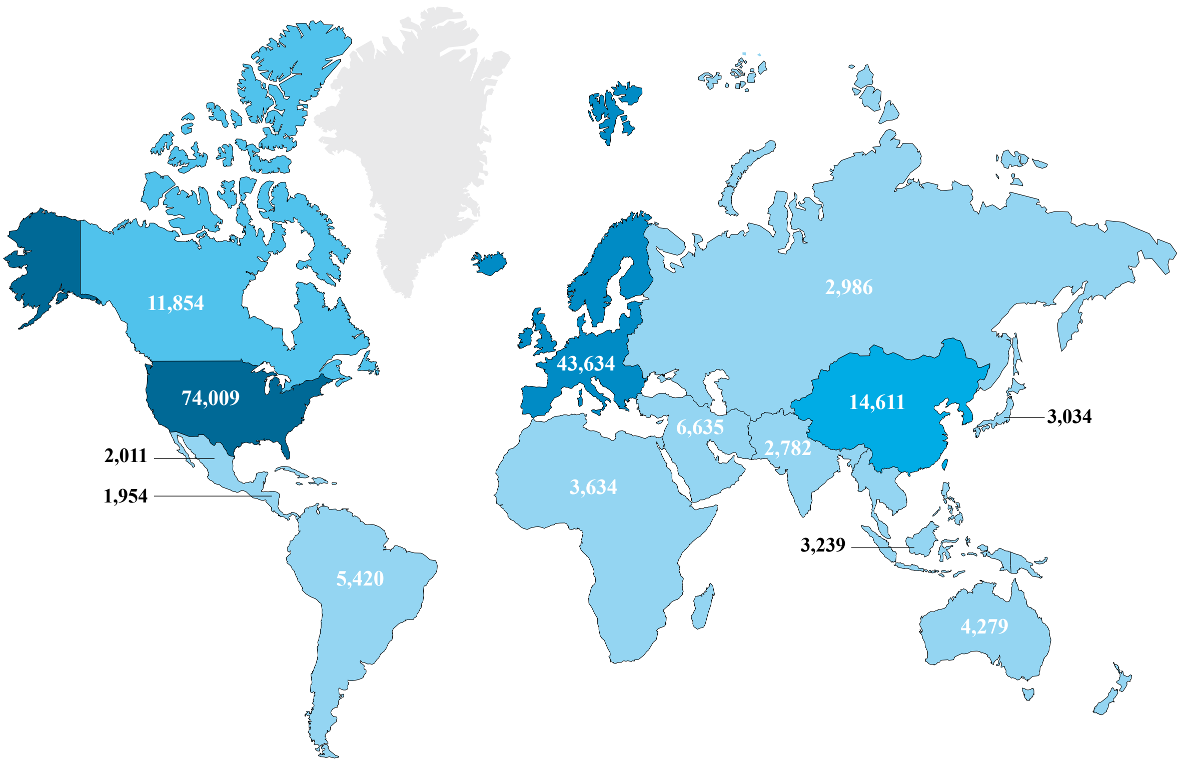
RD healthcare provision and the RD research landscape currently lack adequate structures. Against this background, the BMG and the BMBF, together with the German Alliance of Chronic Rare Diseases (ACHSE) have developed a national action plan for people with rare diseases, which was presented to the general public in August 2013.[202] The national action plan comprises 52 measures designed to assist in the creation of medical care structures, the pooling of competences, and improving research in the field of RD. The aim is to promote cooperative

FIG 18

Number of clinical trials registered worldwide by ClinicalTrials.gov

DATA DOWNLOAD

Number of studies: low — high



Source: own depiction based on http://clinicaltrials.gov/ct2/search/map?map= (last accessed on 10 January 2014).

research and the networking of science and hospitals in a targeted fashion. The national support measures are to be coordinated and supplemented at a European and interdisciplinary level. For the period until 2018 the BMBF has earmarked EUR 27 million of project funding for national and European research cooperation. The Expert Commission welcomes the plan to strengthen cooperative research and the networking of science and hospitals. However, it questions whether the planned measures are sufficient to achieve an adequate pooling of research resources in the area of RD. The question as to whether new organisational forms need to be developed for research into RD also needs to be posed.[203]

The European Union also supports research into RD. For example, within the framework of the 2014–2015 support phase of the Horizon 2020 programme, the development of new therapies for RD is being funded, European Reference Networks supported and ERA NET co-financed in the area of RD.[204]

TECHNOLOGY TRANSFER AND COOPERATION WITH THE PRIVATE SECTOR

B 1–7

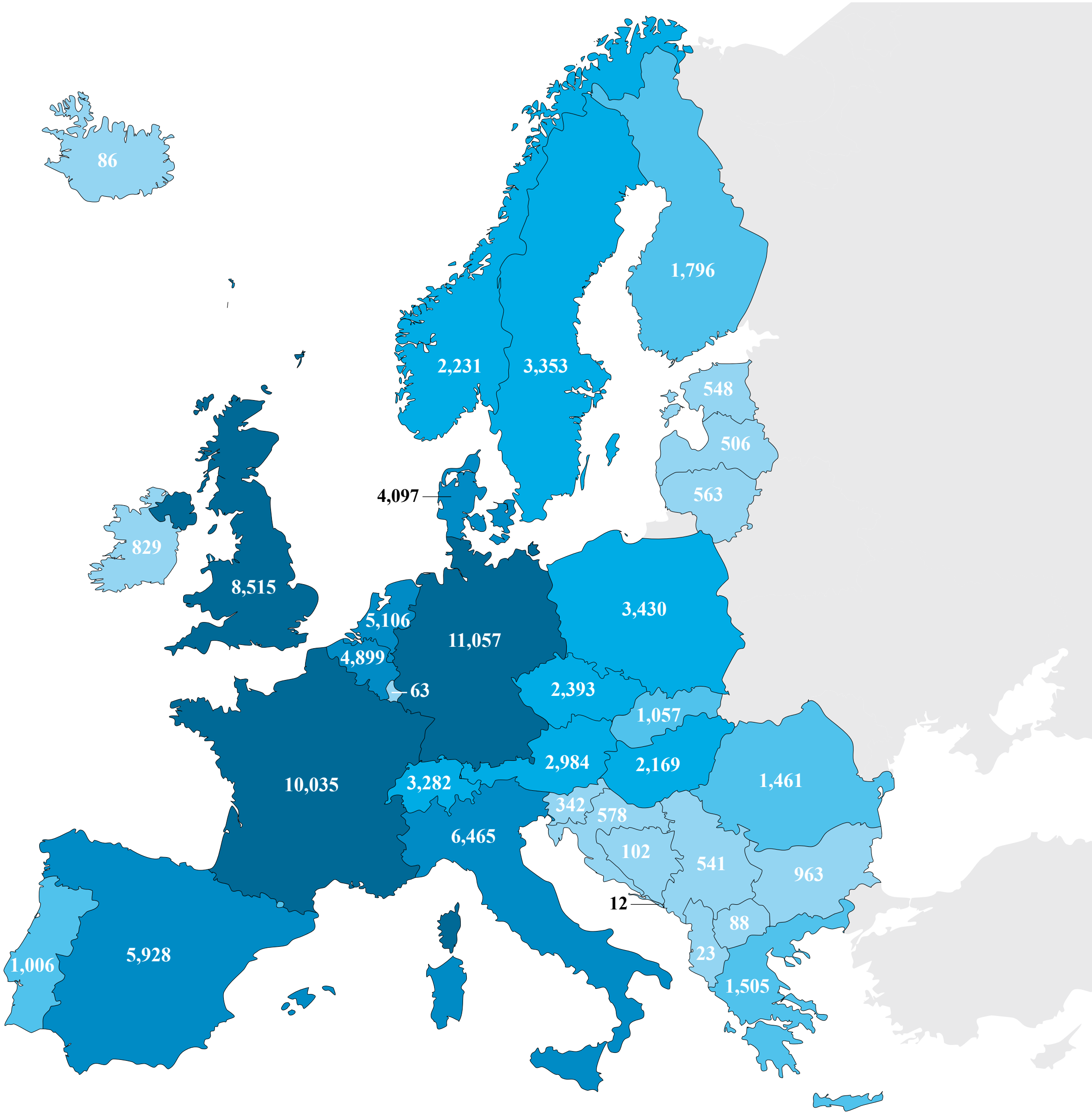
Declining relevance of industry as provider of third-party funding

In 2011, around 26 percent of third-party funding received by university medicine was attributable to industry.[205] These funds amounted to approximately EUR 357 million. In recent years, however, the funding level provided by industry has been stagnating, while external funding as a whole experienced an increase. Between 2002 and 2011, the proportional value of third-party funds from industry sources declined from 39 to 26 percent. In the higher education

FIG 19 **Number of clinical trials registered in Europe by ClinicalTrials.gov**

DATA DOWNLOAD

Number of studies: low ▬ ▬ ▬ ▬ ▬ high



Source: own depiction based on http://clinicaltrials.gov/ct2/search/map?map=EU (last accessed on 10 January 2014).

BOX 06

Rare diseases (RD)

Diseases are classified as rare when they are contracted by no more than five out of 10,000 people.[206] A total of around four million people in Germany and around 30 million people in Europe suffer from one of the estimated 7,000 to 8,000 rare diseases. RD generally have genetic causes, are seldom curable and frequently manifest themselves in several organ systems simultaneously.
For a long time due to high R&D costs and a relatively small sales market, industry showed little interest in bringing medication against RD – so-called orphan drugs – onto the market. Consequently, both the United States and the EU have taken measures to establish incentives for the development and market entry of orphan drugs.[207]

The field of RD poses special challenges, both with respect to patient care and research:[208]

- RD are frequently diagnosed late or not at all. As several organs are generally affected, as a rule, complex and interdisciplinary diagnostics and treatment is required. The causes of many RD have not been researched yet. Consequently, corresponding therapies are frequently unavailable.
- The integration of basic research and clinical research is of special significance for research into RD. However, difficulties resulting from, on the one side, the low number of researchers working on RD, and on the other, the regional distribution of patients, need to be overcome.

sector as a whole, this proportion declined from 26 to 21 percent in the same period.

Clinical trials as core field of cooperation with private sector

The conduction of clinical trials is a core area of cooperation between the university medicine sector and the pharmaceutical industry. Around 80 percent of clinical trials conducted in Europe are commercially sponsored, mostly by pharmaceutical companies (cf. Table 6). The pharmaceutical industry, in turn, expends well above 50 percent of its R&D budget on clinical research.[209]

Clinical trials frequently lead to debates on the contributions made by companies and public institutions and the reimbursement of the university hospitals' costs.[210] Private enterprises are internationally flexible in their choice of partners and often make use of subsidies for clinical trials offered by some countries. In Germany, the costs of clinical trials were inadequately calculated for a long time. Many of the German university hospitals have only recently established adequate cost accounting systems.

Broadening scope of collaborations with private sector

In addition to clinical trials, at least medium-term cooperation projects with a somewhat broader scope have become increasingly important as a means of cooperation between university medicine and industry in recent years.[211] These projects generally start at a much earlier phase of the research process, often starting in the basic research phase. These projects go further than individual studies and may include a broad range of cooperation forms (cf. Table 7). Large pharmaceutical companies choose their university partners at an international level, with a large number of relevant cooperation projects to be found in the United States and Great Britain in particular.[212]

The general public has occasionally expressed the concern that collaborations between university medicine and private enterprises jeopardise the research freedom and independence of university hospitals.[213] To create public acceptance for such collaborations, they should be designed in a way that safeguards the legitimate interests of the company and prevents conflicts of interest on the part of university medicine.

Room for improvement in the area of patent exploitation

In university medicine, technology transfer, i.e. the transfer of academic research and development results to enterprises for the purpose of economic exploitation, has become more important in recent years.[214] The most prominent modes of technology transfer are patent applications and patent exploitation as well as the creation of spin-off enterprises.[215]

TAB 06 **Clinical trials 2005 – 2012 according to source of funding**
(figures in percent)

DATA DOWNLOAD

	2005 (28.1.)	**2006** (03.01.)	**2007** (01.01.)	**2008** (01.01.)	**2009** (01.01.)	**2010** (01.01.)	**2011** (31.12.)	**2012** (31.12.)
commercial	89.0	82.0	81.0	80.0	79.5	79.0	79.0	79.0
non-commercial	10.0	17.0	18.5	19.5	20.0	20.5	21.0	20.0

Clinical trials according to source of funding as a percentage of all clinical trials per year. Residual amount not included.
Own depiction based on Loos et al. (2014) based on https://eudract.ema.europa.eu/document.html#statistics
(last accessed on 6 June 2013).

TAB 07 **Examples of enhanced research cooperations between university medicine and industry in Germany**

DATA DOWNLOAD

Cooperation	**University medicine partners, and non-university research organisation**	**Industrial partners**	**Year**
Strategic alliance for promoting preclinical research in the field of pulmonary vascular diseases – enhanced cooperation in the area of degenerative lung diseases	University of Giessen	Pfizer	2009 and 2013
Financing of a research group at the CPC and iLBD on research into new cell therapy methods with chronic lung diseases	Comprehensive Pneumology Center (CPC, partners: Helmholtz Zentrum, LMU University Hospital Munich, Asklepios Fachklinik München-Gauting) and Institute of Lung Biology and Diseases of Helmholtz Zentrum München	Roche	2010
Endowment of a chair in the field of gastroenterology	University of Erlangen-Nuremberg	Abbott	2010
Scientific collaboration in the field of stroke research – additional partnership within the framework of a diabetes alliance, also including the joint Sanofi-Charité diabetic laboratory	Charité	Sanofi	2010 and 2012
Creation of the public-private partnership research association Boehringer Ingelheim Ulm University BioCenter (BIU) – focus on research into neurodegenerative, cardiometabolic and pulmonary diseases. Jointly funded by Boehringer Ingelheim, the federal state of Baden-Württemberg and the University of Ulm.	University of Ulm	Boehringer Ingelheim	2011

Source: own depiction based on Loos et al. (2014) using data by vfa; own internet research.[216]

Since 2002, universities in Germany have been able to make use of patent exploitation agencies, which have been established mostly at a federal state level.[217] In some cases, e.g. at the Charité Berlin and the University of Heidelberg, medical faculties have established independent technology transfer agencies.

To promote patent applications, a number of major German universities have established their own patent exploitation agencies, among them Munich and Heidelberg. This means that researchers active in these locations are no longer dependent on the respective federal state's patent exploitation agency, but can turn to local experts who are familiar with the researcher's work and his or her specific needs. However, the creation of independent patent exploitation agencies is not an option for small universities.

The introduction of a grace period would mark a further step in promoting patent applications. Researchers at universities are still faced with the dilemma of having to publish or patent their results as swiftly as possible in order to prevail in scientific competition. Since medical research is a dynamic research area with high patenting activity, patenting barriers are particularly problematic here. In the view of the Expert Commission, this conflict could be partially mitigated through the introduction of a grace period.[218]

Venture capital-backed start-up businesses as important innovators in medical research

In the long term it will be important to foster an entrepreneurial culture at Germany's tertiary education institutions, a culture that continues to be comparatively poorly developed in Germany. In the United States and Canada, for instance, entrepreneurial training is part of the curriculum of scientists and physicians. In contrast to that, physicians in Germany receive only little guidance with regard to starting up a business.[219]

Both new enterprises and universities together considerably contribute to the discovery of innovative drugs and the development of drugs related to new fields of application that have not been considered previously.[220]

The development of drugs often incurs high R&D costs in conjunction with relatively high project risks. Due to this, many new enterprises from the life sciences sector are dependent on large sums of venture capital. Yet, in Germany the financing of capital-intensive early-stage projects continues to be an issue.[221] The Expert Commission has repeatedly called for the necessity to improve conditions for venture capitalists, which continue to be unfavourable to date. In the coalition agreement, the governing parties have agreed to adopt a venture capital law to improve the legal and fiscal framework for venture capital based on different financing options.[222] The Expert Commission expressly welcomes these plans.

USE OF ICT IN MEDICAL RESEARCH B 1–8

Information and communication technologies (ICT) are becoming ever more relevant in medical research.[223] In addition to the creation of networks and the use of large amounts of data – to be further analysed in the following example – a range of other topics are also relevant here. These include hardware and software solutions required for genetic research, the support of workflows and quality management in clinical trials, as well as the IT infrastructure used in biobanks.

ICT opens up networks and research resources

Interdisciplinary cooperation and the efficient use of scarce research resources are continuously gaining relevance in medical research. ICT can supply important tools to promote the networking of scientists and the provision of information on available research resources. Open-source solutions for this field of application include Harvard Catalyst Profiles and eagle-i (see Box 7). In future, medical research institutions should make stronger use of the opportunities offered by ICT for networking and the efficient use of scarce research resources.

Availability and use of large data sets becoming ever more important

The term "big data" refers to the analysis of large amounts of complex data from multiple sources with a high processing speed. In biomedical research, the use of such large data sets is playing an increasingly important role. The smart merging, linking and evaluation of such data sets can open up new prospects for research. Big data could provide German and European locations with the chance to distinguish themselves in medical research. Yet, the use of large data sets is often limited by the fact that necessary data infrastructures are lacking and scientists are insufficiently trained in dealing with big data. Further core challenges include the protection of sensitive patient information as well as the development of methods for securing, aggregating and processing heterogeneous, non-standardised data.

To advance the utilisation of clinical data for research, the open-source solutions i2b2 and SHRINE have been developed in the United States (cf. Box 7). The i2b2 software is characterised by its ability to process highly heterogeneous data from multiple hospital information systems.[224] i2b2 is becoming more and more established also in Germany and Europe.[225] In Germany this software is used e.g. at the university hospitals of Erlangen-Nuremberg, Göttingen and Leipzig.[226] Under the umbrella of TMF (Technology, Methods, and Infrastructure for Networked Medical Research), a networking platform for medical research in Germany and within the framework of a research consortium funded by the BMBF, said institutions are working on making i2b2 more accessible to stakeholders from the German research system.[227] Furthermore, a Europe-wide public-private partnership project that also involves large pharmaceutical companies, is also based on i2b2/SHRINE.[228]

The BMBF provides several measures to support the use of large data sets for biomedical research.[229] However, the Federal Government has not yet presented a concerted strategy for tapping the potential of using large data sets for biomedical research. In contrast to that, the NIH initiative Big Data to Knowledge (BD2K) has been launched in the United States, which aims to train bioinformatic specialists and advance the development of data infrastructure (cf. Box 8).

QUALIFICATIONS AND WORKING CONDITIONS IN MEDICAL RESEARCH

Lack of scientific basis in the training of medical students

In recent years, the training of medical students at German universities was increasingly focussed on specialised skills and on strengthening practical medical activities. As practical training elements have been brought to the fore, there are now calls for a stronger scientific focus in the training of medical students. The Association of the Scientific Medical Societies in Germany (AWMF) has pointed out that the current training regulations and their implementation at medical schools pose the risk that "the scientific foundations of medical subjects are not adequately represented in today's academic curriculum."[230]

The practice and patient-oriented design of medical degree courses is often cited as the reason why the interest in clinical research is declining and fewer and fewer medical students opt for an academic career. Furthermore, the lack of scientific quality of doctoral theses in the medical field is another issue that is frequently addressed. In the view of the German Council of Science and Humanities *(Wissenschaftsrat)*, medical doctoral theses often have the quality of a graduate thesis and thus fail to meet the standards of independent research work.[231]

The debate on medical training, and especially the question of balancing practical experience with scientific quality and research relevance, is in full swing not only in Germany, but also in its comparison countries (i.e. the Netherlands, Canada, Switzerland, and the United States). The comparison countries seem to be characterised by a two-staged approach to academic training: while the first stage provides scientific foundations for all students, the second, optional stage provides students with the opportunity to timely choose a research focus and to conduct independent research.[232]

In recent years, a number of medical schools in Germany have introduced specific MD/PhD programmes to improve the academic skills of talented young physicians with a strong interest in research. These programmes provide interdisciplinary research-based academic training in the fields of medicine, life sciences and natural sciences.[233] Medical students with

BOX 07

Use of ICT in medical research – the example of Harvard

Harvard Catalyst Profiles[234]
Harvard Catalyst Profiles is a software tool for creating research networks and for mining specific subject-related expertise. The tool also illustrates how each person is connected to others within the comprehensive research community of the Harvard Medical School, the Harvard School of Dental Medicine and the Harvard School of Public Health. Harvard Catalyst Profiles is based on the open-source Profiles Research Networking Software. This software is used by a large number of institutions worldwide.

Eagle-i[235]
Eagle-i is a national platform developed with the aim of reducing the effort of scientists in search of research resources and avoiding the expense of reproducing existing research resources. Eagle-i was developed by a consortium and has been funded by the National Center for Research Resources (NCRR) to the tune of USD 15 million. NCRR is part of the National Institutes of Health (NIH). Eagle-i currently comprises 50,000 different resources, including resources on reagents, organisms and viruses, biological samples, software, protocols, and core laboratories. Eagle-i is also an open-source platform.

Informatics for Integrating Biology and the Bedside (i2b2)[236]
The i2b2 software facilitates the merging of heterogeneous sets of clinical data and enables the evaluation of data within the framework of translational research. With the help of i2b2, patient cohorts can be selected in a user-friendly manner according to a set of inclusion and exclusion criteria. Today, the i2b2 software is used by a variety of institutions in the United States, and also in Europe and Asia.

The i2b2 software originally emerged from the Research Patient Data Repository (RPDR) developed at Massachusetts General Hospital. In 2004 the Massachusetts General Hospital and the Harvard Medical School successfully submitted i2b2 to be awarded an NIH-grant as a National Center for Biomedical Computing (NCBC). Together with six other NCBCs, i2b2 shall serve as a centre of competence and provide the United States with infrastructure necessary for the efficient processing of clinical data.

Shared Health Research Information Network (SHRINE)[237]
Developed at Harvard, the Shared Health Research Information Network (SHRINE) is based on i2b2 and aims to support researchers in compiling information on large groups of well-characterised patients within a network. Available information currently comprises information on standardised demographic indicators, diagnoses, medications, and selected laboratory results. By returning aggregate patient numbers only, SHRINE ensures the protection of privacy and usage rights of the medical data involved.

SHRINE helps researchers in performing the following tasks: generation of new research hypotheses; planning of research that requires large sample sizes; preparation of grant applications that would benefit from pre-identification and/or pre-characterisation of a potential research cohort; identification of potential cohorts for clinical trials; conduction of research in the areas of public health and health services.

Implemented at Harvard University, the SHRINE network is currently used e.g. by the Beth Israel Deaconess Medical Center, the Boston Children's Hospital, the Brigham and Women's Hospital, the Dana-Farber Cancer Institute and the Massachusetts General Hospital. These institutions are now able to retrieve and evaluate the anonymised data of six million patients.

SHRINE is available as an open-source platform. In the United States there are already several SHRINE networks. In addition, a national pilot project is being conducted to analyse comorbidity in the areas of autism and diabetes. A European consortium spanning five countries is currently evaluating the use of i2b2 and SHRINE for clinical trials, medicine safety and other purposes.[238]

BOX 08

THE NIH Big Data to Knowledge (BD2K) initiative[239]

The use of large data sets is often restricted by insufficient data infrastructures and a lack of qualification among scientists in dealing with big data. To address these issues, the NIH launched its Big Data to Knowledge (BD2K) initiative in December 2012. The initiative aims to support the training of young bioinformatic specialists and to advance the development of data infrastructures. The core elements of this initiative are the establishment of new data centres as well as the creation of Centers for Excellence (CfE) which are to be funded by the NIH to the tune of USD 24 million annually. The Centers for Excellence shall provide impetus by bringing together technical and subject-specific knowledge, thereby improving the analytical skills of the interdisciplinary research teams, while also offering information solutions.

an interest in research can obtain a PhD degree in natural sciences either parallel or subsequent to their medical doctorate degree (MD). Yet, the choice of MD/PhD programmes is still very limited in Germany.[240] Students in Germany who aim for a career in university medicine are still well-advised to invest their time in obtaining postdoctoral qualifications rather than pursuing a PhD in natural sciences.[241] It should also be noted that many physicians with an interest in research often choose to start their specialist medical training (e.g. as an internist, pediatrician, or gynaecologist) immediately after the completion of their general medical studies. These specialist training programmes stretch over five to six years. Such specialist qualification is essential for acquiring a senior position in academic clinical medicine. Yet, early stage clinical training is difficult to reconcile with a PhD degree after the completion of medical studies. If, however, a PhD programme is taken up immediately upon completion of medical studies, it will be difficult to combine this with early stage clinical training.

Dual qualification profiles in the form of MD/PhD programmes are much more common in the United States. This ensures that trained medical professionals with a good understanding of scientific methods are available for research, and that medical research can be closely aligned with the requirements of patient care. The translation of research results into patient care is sustainably strengthened by these physician-scientists and through their work in interdisciplinary teams.[242]

The Expert Commission welcomes the introduction of MD/PhD programmes at German medical schools. The creation of an academic research qualification as a supplement to the existing patient-oriented training contributes to improving the translation of results and to advancing differentiation within the German higher education sector.[243]

Unattractive working conditions for young scientists

Besides these qualification-related issues, working conditions for young scientists are also relevant factors for the international competitiveness of German university medicine. Here it is important to distinguish between factors that play a role for all young scientists in Germany – such as the relatively long qualification phase and a high proportion of temporary positions[244] – and those factors that specifically apply to young scientists in university medicine. These include the strong hierarchies at German university hospitals, issues relating to the recognition of research periods for specialist training, and, most notably, difficulties in combining clinical and scientific activities.

German university hospitals are characterised by steep hierarchies: a fairly small, independent professorial top level is met by a large pool of mid-level and low-level employees with mostly temporary contracts.[245] In fact, there is a general complaint that the predefined hierarchical structures are more alive in medical schools than is the case in other faculties. Hierarchies are less pronounced in the United States, which can be attributed not only to cultural reasons, but also to structural ones. For instance, academic staff in the US are less dependent on their senior professors than those working in Germany.[246] Furthermore, specialist training for doctors is more "school-like" than it is in Germany: in the United States, designated specialist doctors pass through the different training stages according to a set schedule. In Germany, the transition from one stage to another has to be negotiated with the professors in charge. In the United States it is also more common for young scientists to raise their own research funds. Compared with their German colleagues, they are much more independent in their work, but at the same time they are also under stronger competitive pressure.

Another disadvantage for research doctors in Germany is the intransparent system for the recognition of research periods for specialist medical training. Depending on the regional medical association *(Landesärztekammer)* and depending on discipline, recognition regulations can be quite restrictive and at times even ambiguous. In collaboration with the competent regional medical associations, individual university hospitals have developed model curricula to improve the design of training and research activities. However, a comprehensive solution to the problem is currently not in sight.[247]

The difficulty of combining clinical and scientific activities

The so-called triple burden is another phenomenon specific to medical training. While academics at tertiary education institutions are faced with the double burden of research and teaching, academics in medicine are faced with a third burdening factor: patient care. One of the main problems here is the difficulty of combining clinical and scientific activities. Due to cost pressure on the part of the hospitals, medical staff are largely forced into patient care, leaving only little time for research activities.

The German Council of Science and Humanities has pointed out that many university hospitals seem to perceive research as a spare time activity ("off-duty research").[248] Given the burden of clinical work, for aspiring specialist doctors it is difficult to pursue research activities in addition to academic training.[249]

At a number of medical schools, rotation positions are an established instrument used to improve the compatibility of clinical and scientific activities. Research doctors with duties in patient care may be temporarily exempted from their duties to solely work on a scientific project during a given period of time. Rotation positions are promoted both by the DFG via so-called Gerok positions, as well as by the medical faculties themselves. Yet, the number of rotation positions is still very limited.[250] The problem is further intensified by the funding practices of the BMBF and its project management organisation, DLR (cf. page 64).[251]

The problem of reconciling clinical and scientific activities is less pronounced in the United States. Here, the time a physician may allocate to patient care, laboratory work and teaching is clearly regulated.[252] Thanks to this strict regulation, physicians are provided with fixed working hours (protected time) during which they are exempted from clinical duties, enabling them to fully engage in research activities.[253]

In light of the above issues, the Expert Commission has gained the impression that research at German university hospitals is becoming less and less attractive for medical doctors. A lack of incentives and the difficulties of combining patient care and research activities force physicians with an interest in research to restrict their activities or pursue a research career abroad.[254] Yet, it is precisely this combination of clinical and scientific activities that is a prerequisite for the translation of research results – and, ultimately, for medical research and patient care that meets international standards. Given the current circumstances, Germany is running the risk of falling behind in the recruitment of qualified and motivated researchers, while at the same time losing its best talent.

RECOMMENDATIONS

B 1–10

Excellent research and the swift and efficient translation of research results into clinical care are dependent on several factors. An international comparison of medical research locations demonstrates that the geographic proximity of interdisciplinary research institutes, hospitals and enterprises is of particularly great importance in addition to the provision of sufficient funding.

Furthermore, excellence in research also requires a certain critical size of university medicine locations and thus a regional concentration of research institutions. In this context the question arises whether Germany's medical research system is overly fragmented with its 33 university hospitals. In the view of the Expert Commission, these considerations are an argument against the idea of establishing additional locations, unless these locations display extraordinary innovation potential. University hospitals are highly unsuitable as an instrument to ensure appropriate regional representation.

Furthermore, the success of any medical research location depends on the qualification and motivation of its research and patient care staff. Therefore, the key challenge for German medical research lies in creating internationally competitive working conditions for talented scientists and medical staff within a top-class research area.

Strengthening innovative and interdisciplinary approaches

The Expert Commission welcomes the launch of German Centres for Health Research (DZG) as a means of bundling medical research more effectively. As these centres have been established only recently, little is known about the best organisational forms. Decisions on the founding and institutional design of additional DZG centres should therefore be only taken after the existing centres have been evaluated.

Interdisciplinarity and translation should be promoted through the development of scientific collaborations based on partnerships e.g. between universities and non-university research institutions. Funding incentives and experimental clauses could support the development and implementation of new, strong academic profiles in the area of medical research.

Solid funding basis needed for R&D in university medicine

The bearing of the university hospitals' systemic additional expenses should be balanced out. As these expenses can be partially allocated to patient care and partially to research and training, it is disproportionate to burden solely the health insurance companies. However, great care should be applied when creating a balancing mechanism, as the creation of disincentives generally leads to high costs and is not easily corrected. Therefore, political stakeholders should carefully consider the tools to be introduced for balancing out the additional expenses of university hospitals.

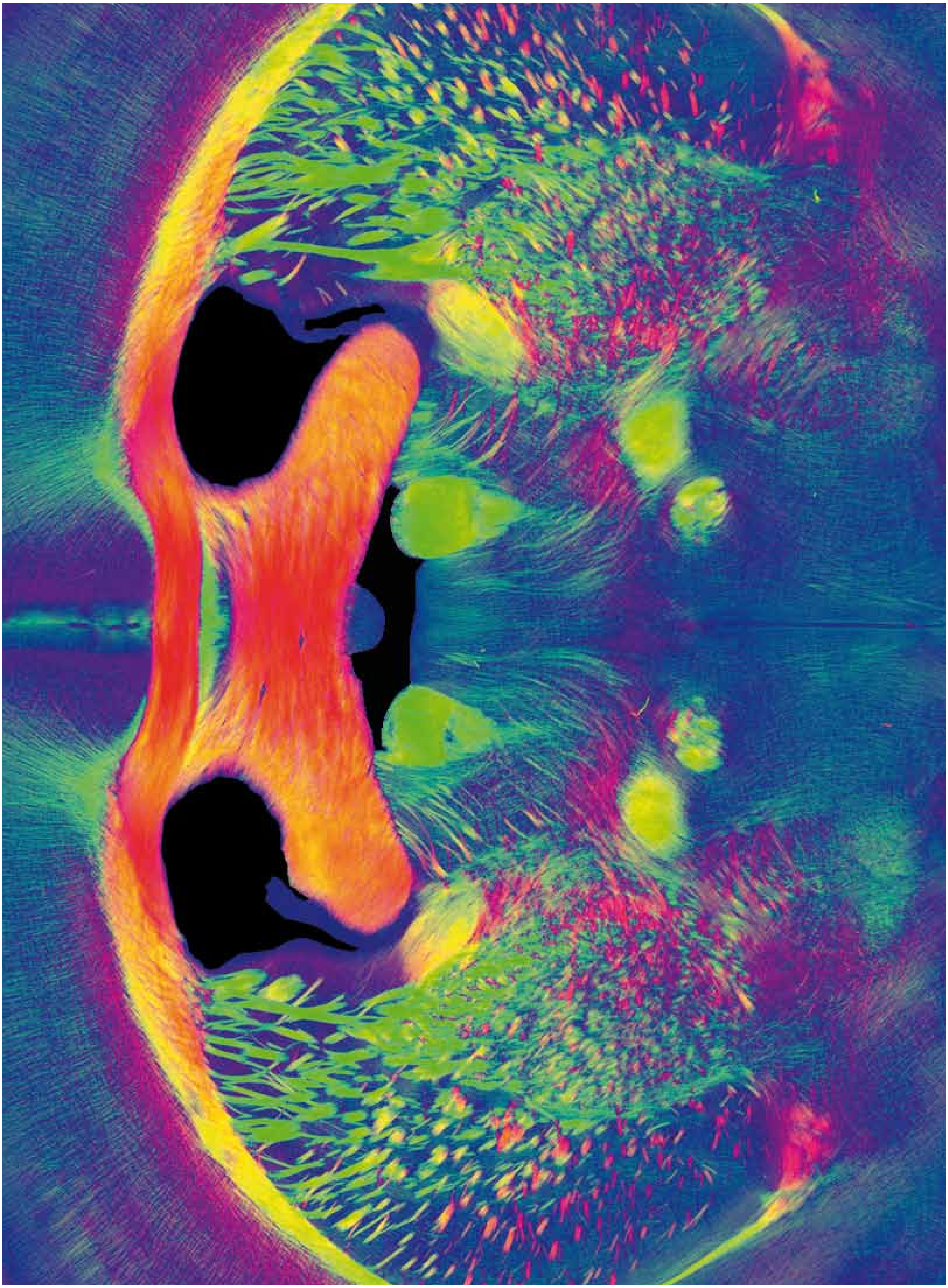
Basic funding for further developing research and teaching should be strengthened not only within the overall higher education sector, but also within medical schools. This should also be facilitated by re-enabling the Federal Government to fund tertiary education institution at an institutional level (cf. the Expert Commission's comments on Article 91b of the German constitution in Chapter A 1). In addition, DFG and BMBF should raise their programme and project allowances within a short time. In the medium term, contracting authorities should introduce a refund of full cost (cf. Chapter A 1). When commissioned with public and private R&D projects, tertiary education institutions must be enabled to charge for the full costs of the project.

Against the background of rising costs and competitive pressure, the Expert Commission recommends concentrating the allocation of research funds for university medicine even further on those locations in Germany that are particularly strong in performance.

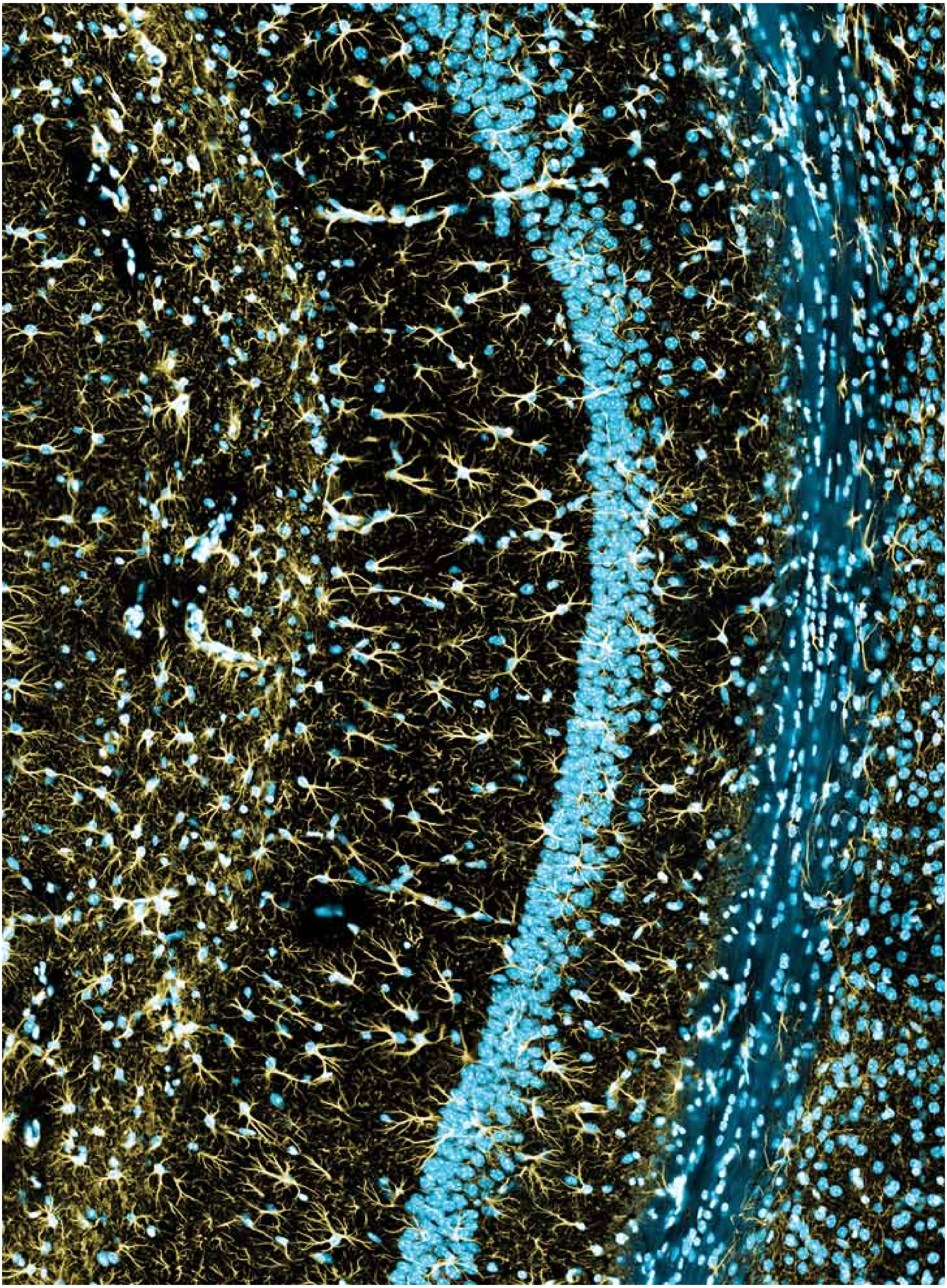
Further strengthening clinical research

The close integration of basic research and clinical research is to be further strengthened. Efforts should be made to promote the geographic concentration of basic research, clinical research and patient care, as well as other stakeholders from the health sector, such as non-university research institutions and businesses.

Centres established in the context of the BMBF structural support measures to improve the framework conditions for patient-oriented clinical research – such as the Coordination Centres for Clinical Trials (KKS) and the Clinical Study Centres – should be developed further according to demand. The relevant establishments should not enter into a publicly subsidised price competition, but should secure a high quality in all clinical trials conducted. Financial self-sustainability must not be the sole success criterion of these centres.



Nerve fibres of the brain in 70 microns thick, histological frontal sections,
visualised with Polarised Light Imaging. Here: fibre flow of a mouse.



Hippocampal and neocortical subregions with fluorescent cell nuclei (blue) and glial cells (yellow)

Setting incentives for corporate collaborations and technology transfer

An ongoing professionalisation of tertiary education institutions in the areas of industrial cooperation, cost accounting and intellectual property exploitation could create incentives for enhanced cooperation between medical schools and private enterprises.

A uniform code of conduct for all university medicine locations could help avoid conflicts of interest within corporate collaborations, while ensuring the highest possible level of transparency – even without mandatory disclosure of cooperation details.

A grace period should be introduced in the European patent systems. Researchers at universities are still faced with the dilemma of having to publish or patent their research results as swiftly as possible to prevail in scientific competition. This problem could be partially mitigated by introducing a grace period in the German patent system. Since medical research is a dynamic research area with high patenting activity, patenting barriers are particularly problematic in this regard.

Since venture capital-based start-ups are important innovators in medical research, improving financing conditions for business start-ups is also an important step towards increasing the competitiveness of German medical research. In previous reports, the Expert Commission has already outlined the components of internationally competitive framework conditions for investors.[255] In the training of medical researchers, topics relating to entrepreneurship should be addressed to a much greater extent than previously.

Tapping innovation potential through the use of ICT

University medicine sites and non-university research organisations active in the field of medical research should make intensive use of the opportunities offered by ICT to facilitate networking and the efficient use of scarce research resources. The Expert Commission is very concerned about the fact that Germany's shortcomings in the field of ICT are hampering medical research. The Federal and Länder governments should develop an action plan for the use of large sets of complex data in medical research. In the view of the Expert Commission, this action plan should be integrated into the Federal Government's Digital Agenda (cf. Chapter B 3).

The handling of big data in medicine also calls for an active, solution-oriented debate on data protection issues in order to facilitate the inter-institutional use of patient data for research purposes, while also ensuring sufficient protection of the patients' privacy. Procedures for the anonymised use of patient data should be applied for the purpose of releasing innovation potential without compromising privacy.

Strengthening the scientific components of medical studies

As a general rule, it would make sense to subdivide medical careers into two pathways, one with a scientific focus, and one with a focus on the medical profession.

Tertiary education students with an interest in research must be given the chance to specialise in research topics at an early stage. MD/PhD degree programmes should be expanded further in Germany.

Research careers in university medicine need to be more attractive

In Germany, a career in medical research is less attractive than in other countries. Against this background, German medical research is at risk of losing more and more talented young professionals and of decreasing research quality. A lack of incentives and the difficulties in combining patient care and research activities are the main reasons for these shortcomings.

In order to reconcile research and patient care to a greater extent, German university hospitals should follow successful international examples and introduce additional rotation positions. The Expert Commission recommends introducing fixed time frames (protected time) for research. In the view of the Expert Commission, young scientists are indeed left with too little time for their own research.

General reforms are also needed in the specialist training programmes for doctors, which currently entail a high degree of uncertainty for physicians active in research. The specialist training phase should be clearly structured and predictable, as is the case in the United States. The creation of transparent recognition regulations for research periods during specialist training would be a step in the right direction. Regulations should uniformly apply to all of the federal states. Depending on the competent regional medical association *(Landesärztekammer)* and depending on discipline, regulations still vary today and continue to be ambiguous at times.

To attract young talented physicians to research, German universities need to offer more favourable career prospects. Research careers are less predictable at German universities, and youngresearchers are highly dependent on their supervising professors. It is often the case that this dependency does not provide sufficient leeway for independent research. New funding and scholarship programmes should be introduced, and existing programmes such as the Emmy Noether programme should be expanded to create room for young physicians with an interest in research.

Improvements are also needed with regard to the financing of research projects. The funding practice of the project management organisation DLR, which operates on behalf of the BMBF, is considered as bureaucratic and unattractive when compared with that of the DFG. Therefore, funding practices should be handled more flexibly.

The remuneration of physicians active in research should be brought more in line with the level of remuneration received by physicians engaged in healthcare activities. The current pay gap reduces the attractiveness of careers in medical research at universities.[256]

B 2 INTERNATIONAL MOBILITY OF SCIENTISTS AND INVENTORS AND ITS IMPACT ON INNOVATION

When scientists or inventors are internationally mobile, knowledge is disseminated, new combinations of knowledge occur and innovation is facilitated. The balance of inward and outward migration flows[257] displays systematic cross-country differences – thus resulting in diverging stimuli for innovation. In an international comparison, Germany – as detailed in sections B 2 – 1 to B 2 – 3 – has a rather moderate balance. The results can be summarised in a few sentences and are rather sobering.

Scientists: In an international comparison of mobile scientists as a proportion of all a country's scientists, Germany is ranked in the middle field. Germany loses many of the best scientists as a result of migration. Although there are also returnees, Germany does not succeed in winning back scientists of the same quality on average.[258] Germany at the same time is successful in improving the knowledge pool with new inflows of foreign scientists who have a comparatively high impact (number of citations), but it is not successful in keeping the best of them. Consequently, Germany manages to retain or bring back but a few of the really good scientists. Particularly for the best scientists (highest impact numbers), the German research system does not currently appear to be attractive enough.

Inventors: In international comparison, patenting inventors from Germany display a moderate, slightly decreasing migration rate.[259] At the same time, in international comparison, immigration to Germany is ranked in the middle field at best. However, there are systematic differences in the mobility patterns of the various industries. International inventor mobility freezes Germany's R&D specialisation profile: technology fields in which Germany is strong tend to display a low migration rate and technology fields in which Germany is weak tend to display a high migration rate.

Innovation capacity could be increased if Germany's research and innovation system was made more attractive, especially to top scientists and inventors.

THE MOBILITY OF PUBLISHING SCIENTISTS IN INTERNATIONAL COMPARISON B 2 – 1

The mobility of scientists is not measured in official statistics but it can be mapped using a range of different proxy indicators (cf. Box 9). A current study[260] examines the international mobility of scientists from 36 countries based on data from the publication database "Scopus Custom Data Elsevier". The analysis covers scientists who have published in the period from 1996 to 2011. A distinction is made between "stayers" and "movers", whereby the latter distinguishes "returnees" and "new inflows".[261] The results are presented in Figure 20.[262]

Between 1996 and 2011 there was a total of 19,521 new inflows and 23,460 outflows of publishing scientists in Germany (cf. Figure 21). With a negative balance of around 4,000 outflows, Germany was only ranked 19th in international comparison and thus significantly below the majority of the other OECD and BRICS countries.

Germany ranks in the middle field in the proportion of internationally mobile scientists

In international comparison, Germany benefits from the immigration of internationally mobile scientists to a moderate degree. The level of immigration is ca. 10 percent, of which just under two-thirds are returnees and just over one third new inflows.[263] However, the United States are ranked even lower as regards inflows, situated in the bottom third (with a level of inflows of 7.5 percent, of which around one half are returnees (3.7 percent) and around one half new inflows (3.8 percent)).[264] It is striking that Switzerland scores much better in this regard than either Germany or the United States. With a level of almost 20 percent, of which more than 10 percent are new inflows and 8.5 percent returnees, Switzerland is the top country in terms of knowledge inflow. Switzerland thus has a higher proportion of returnees than Germany (6 percent) or the United

BOX 09

Mobility indicators for scientists and inventors

Author affiliation in scientific publications can serve as the starting point for developing a mobility indicator for scientists in order to establish whether a change of affiliation and country has occurred over time. For example, the OECD study "Researchers on the move" is based on this indicator.[265] In a similar fashion, a change of an inventor's residential address documented in patents can serve as an indicator for a change of country;[266] alternatively, certain patent application procedures collect information on the nationality of the inventor.[267]

However, both indicators are subject to similar problems. They only record mobility for scientists with publications or inventors with patents. As a consequence, mobility is systematically underestimated as persons who have not (yet) published or filed patents are not recorded. In particular, this leads to an underestimation of the mobility of younger people, i.e. those in or prior to the post-doctorate phase. This also applies to mobility in disciplines or technologies where neither publications in international journals nor patents are standard. An additional problem with the publication indicators is the fact that publication is often delayed. In turn, it is not always clear where the publication was actually written (especially shortly after moves or during frequent moves).[268] If a scientist or inventor is recorded for the first time it is possible that the country of origin does not correspond with either the person's nationality or the country where they receive education and training. For example, foreign students who moved to Germany to study and earn a doctorate degree and published for the first time during their stay in Germany, and then returned to their home country, are recorded as "outflowing German" scientists. Conversely, Germans who travel to the United States after their studies in order to earn a doctorate degree, publish for the first time while there and then return to Germany are recorded as "inflowing US" scientists. Such indicators are thus especially diffuse when it comes to recording the country that invested in education and training or assessing the quality of a national education and training system. In contrast, they are more meaningful when it comes to mapping the international knowledge flows during the course of a scientific career and the resulting productivity effects in the country of origin or destination.

However, an advantage of both the publication and patent based indicators is that they provide a complete picture of all the scientists who are actively publishing and patenting. The data is not subject to any sampling bias, non-response bias etc. They even provide reliable information on small scientific disciplines, countries or regions.

Other options for measuring international mobility include surveys among mobile scientists, e.g. within the context of the GAIN network, secondary analyses of the administrative data of mobile scientists from funding programmes, e.g. the Alexander von Humboldt stipends[269] or European Research Council (ERC) grants, as well as the analysis of official statistics such as the Microcensus, Social Security Records or similar data sets.[270] Here it is primarily demarcation problems and small sample sizes which pose problems for a detailed analysis.

States (3.7 percent). It appears that Switzerland is especially successful at bringing back mobile scientists.[271] Austria, Canada, Sweden and Belgium show a similar success to Switzerland in respect of the inflows of scientists.

However, it is not just the number of inflows or outflows of scientists that is important for a country's innovation capacity, but also their quality and performance.

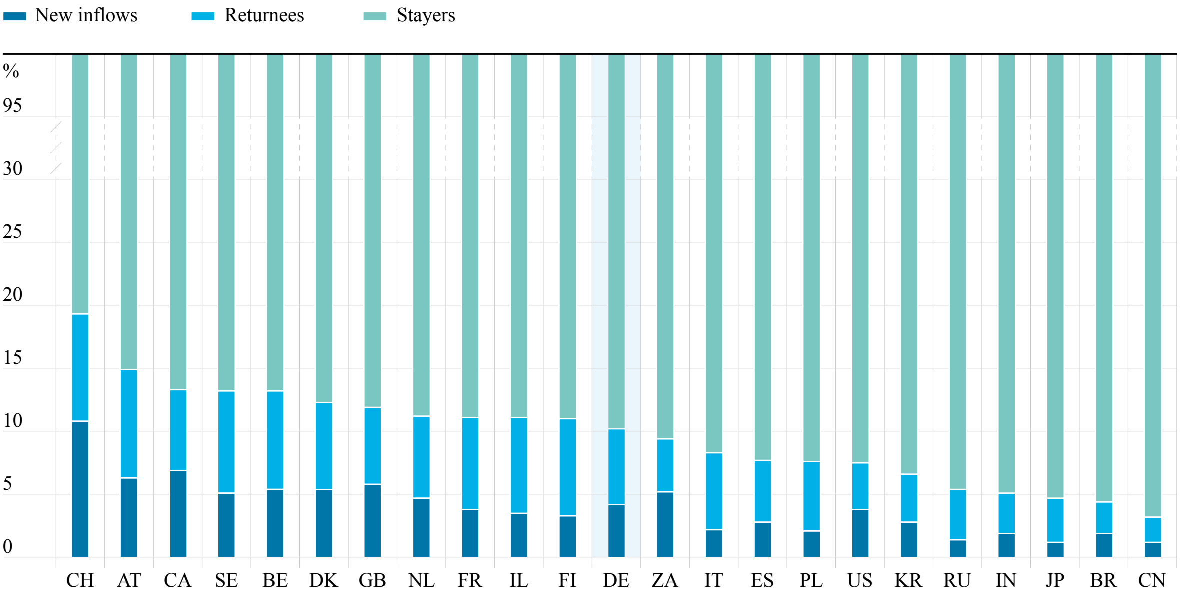
On balance Germany loses especially the best scientists

In order to account for differences in scientific quality and performance, the OECD (2013b) employs the so-called "SNIP Impact Factor". This measures the quality of a journal's authors according to the number of citations the journal receives.[272] Figure 22 provides an overview of the relative quality of stayers, inflows (returnees and new inflows) and outflows. It shows that in Germany – as in other countries except the United States – the outflows have the

International mobility patterns of publishing scientists in international comparison
(shares of stayers, returnees and new inflows among all publishing scientists of a country between 1996 and 2011)

FIG 20

DATA DOWNLOAD



Source: own depiction based on OECD (2013b: 1).

How to read: between 1996 and 2011, approx. 4 percent of publishing scientists in Germany were "new inflows", approx. 6 percent were "returnees" from abroad and approx. 90 percent were "stayers".

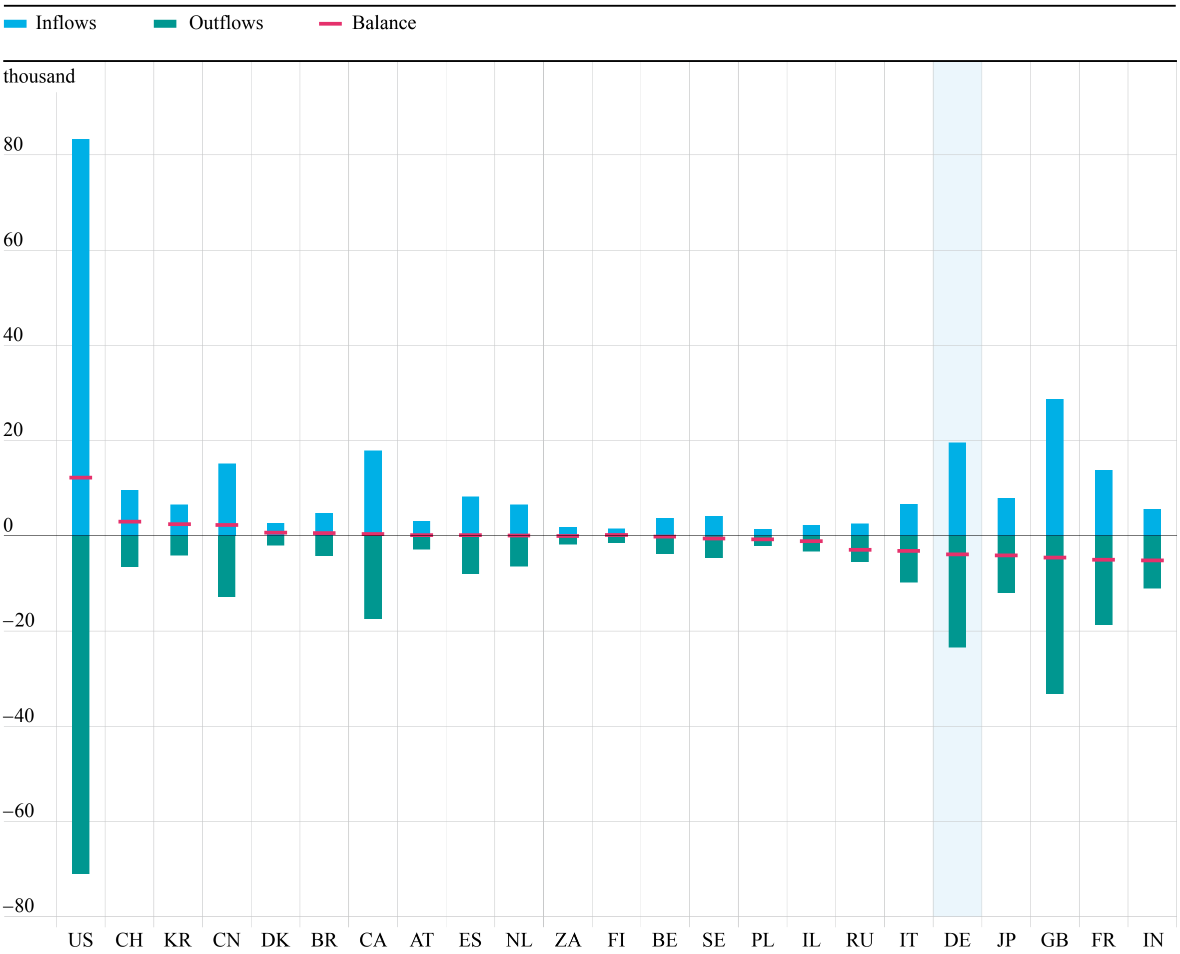
highest impact factor (1.212), followed by new inflows (1.202) and returnees (1.168), while the factor for stayers is considerably lower (1.030). One decisive factor for the change in the knowledge pool, and thus Germany's innovation capacity in international competition, is the relative quality of the inflowing scientists compared to those outflowing, illustrated in Figure 23. In countries to the left of the 45 degree line, the outflows have a higher impact than the inflows. In countries to the right of the 45 degree line, the reverse is the case. Germany is situated to the left of the 45 degree line, i.e. outflows from Germany have a higher impact factor than inflows, so that the international mobility of scientists tends to lead to a reduction in the research quality in Germany.

In the United States, the international mobility of scientists systematically contributes, via various channels, to a continual improvement in research quality: inflows are characterised by scientists with above-average impact (especially in the case of returnees, but also new inflows), and outflows are characterised by scientists with below-average impact. The United States are the only country in which outflows (triangle; 1.202) display a lower impact factor than stayers (square; 1.209). As a result, migration in the United States – if only slightly – contributes to an improvement in the average quality of scientists. In all other countries, the stayers have on average the lowest impact factor, which is often considerably lower than that of the mobile scientists.[273] In the United States, the returnees (1.389) have the highest impact factor in comparison to all other scientists and all other countries. This means that following a stay abroad, it is apparently only the best scientists, who actively published in the United States prior to leaving, that return to the US. The outflowing scientists, who have on average lower impacts, do not return to the United States but remain in new target countries.[274] Furthermore, as the new inflows (1.243) in the United States have a higher impact factor than the outflows, the international mobility of scientists contributes to a continual improvement in the United States' knowledge base.

Similar inflow effects as those in the US are observed in the Netherlands, Great Britain and Canada thanks to a high number of very good returnees. In the Netherlands and in Canada, there

FIG 21 **Inflows and outflows of publishing scientists between 1996 and 2011**
(figures in thousand)

DATA DOWNLOAD



Sorted by balance in descending order.
Source: own depiction based on OECD (2013b).

How to read: approx. 20,000 scientists were new inflows to Germany, while approx. 24,000 were outflows from Germany. Germany thus has a negative balance of approx. 4,000 individuals.

is still an outflow of even the best scientists – a phenomenon that cannot be observed in the United States. In Great Britain, however, it is scientists with a low impact factor that tend to outflow, but their impact is still higher than that of the stayers.

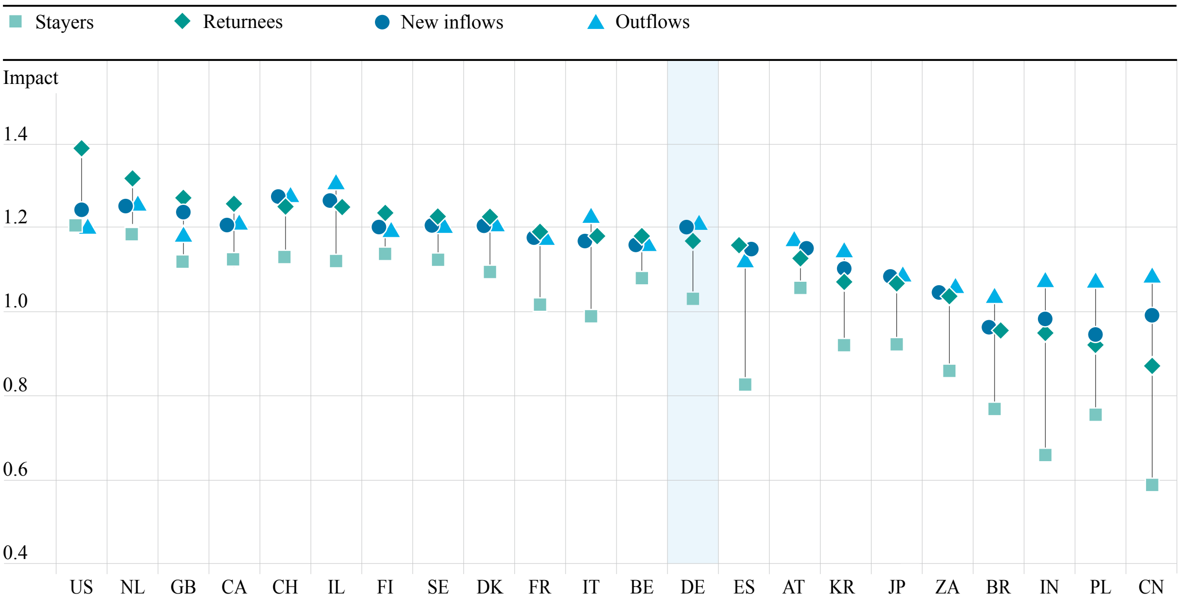
The mobility pattern in Switzerland displays a special feature. This country is consistently improving its knowledge pool through an inflow of excellent new scientists and the ability to win back or keep the best scientists. Switzerland has the highest impact level amongst new inflows (1.277) and a very high impact level (the fifth highest) amongst returnees (1.250). At the same time the impact factor of outflows (1.276) is slightly below that of new inflows. This is also reflected in the very high impact factor of Switzerland's stayers (1.130) in international comparison.

In comparison to the above mentioned countries, the effect of international mobility is less positive for Germany's knowledge pool. The best scientists outflow, but seldom return to Germany once they have left.[275] They remain in attractive research destinations abroad.[276] In this context, a survey among natural scientists at academic institutions[277] shows the importance of outflowing German scientists for the United States and European countries such as the Netherlands, Belgium, Denmark, Sweden, Switzerland or Great Britain. With up to 36 percent, German

FIG 22

Scientific impact of movers and stayers among publishing scientists between 1996 and 2011

DATA DOWNLOAD



Source: own depiction based on OECD (2013b).

How to read: "outflows" from Germany have an average impact factor (median) of 1.21; "new inflows" have the second highest impact factor (1.20), closely followed by "returnees" (1.17). "Stayers" display the lowest impact factor (1.03).

natural scientists represent the largest group of foreign scientists in the respective countries.[278] Furthermore, regarding impact factors, the data show that the average impact of outflowing scientists from Germany (1.212) compares well with the average impact of scientists coming from other countries (Canada: 1.210; Sweden: 1.207; Denmark: 1.206) or is only slightly lower (US: 1.243; Great Britain: 1.236). However, few of the best scientists can be retained or brought back. The German research system seems to hold little attraction for the best scientists.

A ray of hope is that close to one third of all German scientists doing research abroad plan to return to Germany in the long term. A further third report that they would consider returning if there were suitable job offers. Only Swiss, Canadian and Swedish scientists report a higher likelihood of returning to their homeland.[279] Therefore, an improvement in the framework conditions for top scientists in Germany – in combination with corresponding returnee programmes which remove organisational hurdles for returning – could have a sizeable positive effect in the longer term.

For these reasons, the Expert Commission welcomes the introduction of measures to win back excellent scientists from abroad. Such measures (cf. Box 10) are important and deserve the full support of the Federal Government.

Furthermore, measures launched by the Excellence Initiative may already be highly attractive to scientists abroad. Although systematic evaluations of the Excellence Initiative's causal effects on the mobility of scientists, in particular on returnees to Germany, have not been conducted so far, descriptive results indicate a positive effect: whereas in 2011 the proportion of foreign staff within the entire university system was 10 percent, the proportion in graduate schools was 36 percent, in Clusters of Excellence 24 percent and in the Future Concepts *(Zukunftskonzepte)* 37 percent.[280] The large number of well-established scientists from the US who were recruited within the context of the initiative suggests that this also includes numerous German returnees from US research institutions (cf. Box 10). However, the Expert Commission currently has no evidence that the initiative has resulted in systematic "group appointments" of entire research teams from abroad.

FIG 23 **Relative impact of inflowing and outflowing publishing scientists between 1996 and 2011**

DATA DOWNLOAD

Source: own depiction based on OECD (2013b: 3).
*Average of new inflowing and outflowing scientists

How to read: Germany is positioned left of the 45 degree line, i.e. outflows have a higher average impact factor (median) than new inflows. The size of the circle ndicates that Germany has a relatively high total number of mobile scientists.

BOX 10

Returnee programmes for the recruitment of German scientists abroad

Several mobility programmes initiated by the German Research Foundation (DFG) aim to recruit foreign scientists, and in particular, target the return of top German scientists from abroad. These include, amongst others, the Heisenberg programme, the Emmy Noether programme, the "Research Stipends" programmes, and in particular, support measures within the Excellence Initiative which may have contributed to the return of excellent scientists to German institutions.

The DFG's funding statistics do not provide detailed information on the international transfer of scientific personnel or returnees to Germany, especially with respect to the nationality of the scientists. However as early as 2008 – in the first phase of the Excellence Initiative – more than 20 percent of the around 4,000 scientific posts were awarded to scientists who had previously researched abroad. In 2011 this had risen to 30 percent. In the graduate schools the proportion of foreign scientists was 36 percent (2008: 26 percent); in the Clusters of Excellence it was slightly lower at 24 percent (2008: 23 percent).[281] Within the context of the Future Concepts funding line *(Zukunftskonzepte)* around 37 percent of the scientific personnel came from abroad.[282] Important regions of origin for scientists at the graduate schools and Clusters of Excellence in 2008 were Europe, Asia and North America. While primarily postgraduates were recruited from the Asian countries, the majority of scientists recruited from Europe, and in particular North America, were in more advanced stages of their careers.

The Emmy Noether programme is directed at young foreign and German scientists who plan to establish their own scientific group at a German research institution. The funding generally extends over a period of five years. In 2012 the DFG approved 58 new projects. This represents an approval rate of 22 percent. The programme was systematically evaluated in 2008, including the long term mobility of the funded individuals:[283] Although only 8 percent of the Emmy Noether stipends awarded between 1999 and 2006 went to foreigners, almost 25 percent of stipend winners were working abroad after funding had ceased – and thus 5 to 10 percent more than the estimated figure for post doctorate scientists in general.[284] The motives of outflowing stipend winners were, above all, the lack of career opportunities and unsatisfactory remuneration in Germany.

The research stipend programme of the DFG also contains a funding line for German returnees from abroad; 58 applications from such scientists were approved in 2012.[285]

B 2–2 EMPLOYMENT OF FOREIGN SCIENTISTS IN GERMANY AND THE UNITED STATES IN COMPARISON

In this section, instead of the migration flows of actively publishing scientists, the focus is on the stock of foreign scientists employed in Germany[286] as well as an illustrative comparison with the United States. The legal framework for the employment of foreign scientists in Germany is described in Box 11. Overall, the observed employment patterns for foreign scientists in Germany and in the US confirm the above identified mobility patterns of publishing scientists.[287]

Improving the knowledge pool of highly qualified workers in the US – reducing shortages of low-skilled workers in Germany

If scientists are identified by the occupation they work in,[288] and if their citizenship is used as an indicator for their country of origin,[289] then, ca. 135,000 out of a total of 2.47 million people employed in scientific occupations in Germany in 2010 were immigrants. Almost half of them were engineers, architects or scientists in related occupations (67,000), a further 24,000 were computer scientists and 23,000 social scientists. The proportion of foreigners in scientific occupations was thus significantly lower (5.5 percent) than for non-scientific occupations (10.8 percent) – and has even fallen since 2007.[290] Obviously, immigration in Germany plays a greater role in

BOX 11

Legal basis for the immigration of scientists

On principle, EU citizens enjoy freedom of movement of persons and services.[291] In addition, Swiss citizens are granted the same rights. Furthermore, additional bilateral agreements between the EU and third countries such as for example Turkey apply.

Citizens of other countries are eligible for a German residence permit as regulated by the German Residence Act *(AufenthG)*. On the one side, scientists can immigrate in accordance with clause 20 of the *AufenthG*, specially drafted for this purpose (established in 2007 on the basis of the Directive 2005/71/EC for the migration of scientists to the EU). On the other side, there are and have long been additional possibilities for foreign workers, irrespective of their profession, to obtain a residence permit for employment in Germany. These options have been in place before the introduction of the special clause for scientists. Naturally, these options can be and are also used by scientists.[292]

The granting of a residence permit in accordance with clause 20 of the *AufenthG* is subject to a series of conditions. The first condition is that the foreign scientist has a corresponding educational qualification. The second condition is that the foreign scientist has signed a hosting agreement with a recognised research institution. Furthermore, the livelihood of the foreign scientist must be guaranteed, which according to the implementation provisions is given when the scientist has a minimum monthly income of EUR 1,703 in the old federal states and EUR 1,493 in the new federal states. In this context, the Federal Office for Migration and Refugees correctly points out that providing proof of such a net income is a great hurdle. This frequently requires a full E13 position; however, in practice, postgraduates or foreign scholars are often only offered a part-time position. In such cases where the minimum income has not been reached, proof of a guaranteed livelihood can also be provided by way of an individual assessment. This involves, above all, assessing whether current income from sources such as stipends are sufficient to reach the above minima.[293] If, according to the assessment, the livelihood is not guaranteed, then no residence permit can be granted. A positive feature is that an analysis of the labour market conditions is not required prior to the granting of a residence permit in accordance with clause 20 of the *AufenthG*. According to a study, at the end of 2011 only 588 people were living in Germany with a residence permit granted in accordance with clause 20, whereby the majority were relatively young (between 25 and 34 years of age).[294] They came mostly from China, India and the United States. The main destinations in Germany are the federal states of North Rhine-Westphalia (NRW), Baden-Württemberg and Bavaria.[295] The number of residence permits granted over recent years has risen continually.[296] However, the steadily increasing numbers should not disguise the fact that the absolute number of residence permits granted according to clause 20 is still very low. This may be due to the fact that comparatively few research institutions (180) possess an accreditation for the granting of hosting agreements. One of the reasons for the low take-up is that the research institutions must commit themselves to covering the costs should the foreign researchers outstay their residence permit. This is especially problematic for universities when the research is funded by third-parties.[297]

Furthermore, foreign scientists, just like other employees from abroad, are eligible for a temporary or unlimited residence permit when moving to and working in Germany in accordance with clause 18 or clause 19 of the *AufenthG*. They can apply for either a (temporary) residence permit or an (unlimited) settlement permit. The precondition for obtaining either one of these permits is a concrete job offer. Furthermore, both residence permits require a labour market need, i.e. the Federal Employment Agency must explicitly authorise the granting of the permit – unless regulated differently by international agreements. Both types of residence permit are granted e.g. to management staff, workers in the fields of science, research and development, IT specialists or academics. For highly qualified workers an unlimited settlement permit can be granted in special cases.[298]

Since 1 August 2012, highly qualified scientists from third countries can move to Germany for a period of employment of between one and four years on the basis of the “EU Blue Card”. This also requires a minimum income, which is equivalent to two thirds of the income threshold for contributions to the pension insurance (or 52 percent in the case of professions for which there is a special need).[299]

Finally, citizens of third countries who intend to enter Germany for the purpose of self employment or the founding of a business, can obtain a residence permit according to clause 21 of the *AufenthG*. The precondition for this permit is that there is a special economic interest or regional need and that a positive effect on the economy can be expected. Furthermore, the financing must be secured by either the individual's proprietary capital or a loan commitment. An initial residence permit for self-employed persons is in principle temporary and is granted for a maximum of three years; once the business idea has been successfully realised and the means of subsistence is guaranteed, then an unconditional settlement permit can be granted.[300] Surveys among foreign (self-)employees have shown that so far the majority of scientists from third countries have come to Germany by means of residence permits granted according to clauses 18,19 or 21 of the *AufenthG* – and not by means of the special clause 20.

reducing shortages of low-skilled workers than expanding the pool of highly skilled scientists. Similar findings, if not so striking, emerge if one identifies scientists according to their employment sector, not their occupation.[301]

A comparison of employment structures of foreign scientists in Germany with the United States confirms patterns observed in the publication data: it is the highly qualified scientists with a doctorate that tend to immigrate to the United States. However, the result very much depends on how "scientists in the USA" are defined. In the case of a broad definition of academics (ISCED 5 + ISCED 6), the proportion of foreign "scientists" is low, while in the case of a narrow definition (ISCED 6 only, i.e. only those with a doctorate degree) the proportion is very high. On the other side, the proportion of foreign employees with no or only a low qualification (ISCED 1 + ISCED 2) is also higher than that of native employees. So obviously in the US, the workforce is supplemented by foreign immigrants in the least qualified and the highest qualified sectors. German academics, and in particular those with a doctorate degree, contribute significantly to improving the United States' knowledge pool.[302] Over 14 percent of all the Germans employed in the US have a doctorate (ISCED 6)[303] – with an upward trend.[304] At the same time, only 1.4 percent of the native employees have a doctorate.[305] If one takes a closer look at the occupations, immigrants from Germany display a very balanced occupational structure. The largest single share is that of the university teachers with 5.4 percent,[306] followed by life, natural and social scientists (4.8 percent), employees in IT and mathematical professions (4.6 percent) as well as architects and engineers (4.4. percent).[307] If one takes into account that the proportion of university teachers amongst the native population in the US is only 0.9 percent and that of the life, natural and social scientists only 0.7 percent, then this shows once again that the pool of highly qualified scientists in the US is improved by German immigrants.

MOBILITY OF PATENTING INVENTORS IN INTERNATIONAL COMPARISON B 2–3

Patents provide legal protection to innovative technical ideas and therefore are often used as an indicator for measuring the innovation performance of an inventor, a company or research institution, or a country. If patenting inventors move across borders, then innovation capacity changes at the different levels.

Current studies on inflows to the US have shown on numerous occasions that the inflow of highly qualified inventors has a positive effect on the innovation activity of companies, start-ups or research institutions in the destination country.[308] A more recent study[309] has shown, for example, that in the period from 1940 to 2000 inventors inflowing to the US registered twice as many patents as native inventors.[310]

Only a very limited number of reliable studies is currently available for Germany. However, they point at least to the positive effect of cultural diversity on the patenting of highly qualified inventors and the start-up intensity at regional level.[311] Studies which assess the effect of outflows of highly qualified inventors on companies and research institutions in Germany are currently not available.

Available patent statistics focus on the outflow movements of those inventors who possess high quality patents.[312] Mobility of inventors has a wide variety of causes. These include, amongst others, intra-firm mobility of R&D personnel in multinational enterprises (MNEs), patenting scientists moving to a research institution abroad, or possibly starting a business abroad (cf. in more detail Section B 2–5).

Moderate but selective outflows of patenting inventors from Germany

In international comparison, as shown in more detail below, patenting inventors from Germany display a moderate outflow rate. This is characterised by systematic industry differences in the mobility patterns. International inventor mobility thus contributes to freezing Germany's R&D specialisation profile: technology fields in which Germany is strong tend to display a low outflow rate and technology fields in which Germany is weak tend to display a high outflow rate. For multinational enterprises, the outflow of inventors is associated with less knowledge loss than for small and medium-sized enterprises (SMEs) if the migration takes place within intra-firm R&D networks.[313] The number of German inventors working in public research sectors abroad is disproportionately high especially in research institutions in the United States. In addition, there is a high incidence of German inventors founding high-tech companies in the US.

Around 6 percent of the inventors patenting in Germany in 2000, were – according to the their address – internationally mobile inventors between 2000 and 2009.[314] At the same time, according to a current study[315] the percentage of mobile German inventors abroad has grown significantly in the period between 1990 and 2010.[316] Despite this relatively strong growth in the past, the outflow rate for inventors is still higher in the majority of the other OECD countries (cf. Figure 24).[317] Only the United States, Japan and Korea display a lower, and in some cases declining, outflow rate for national inventors.

Interestingly, the United States and Switzerland combined currently recruit more than 50 percent of all inventors of German origin (German inventors) living abroad.[318] German inventors appear to be among the most important founders of high-tech companies in the US (if one assumes that the founding of a high-tech company goes hand in hand with a patent). A study has shown that Germany – measured in terms of its contribution to the total number of foreign company founders and foreign patenting inventors – is already in fifth place in the US and thus only ranked behind foreign founders and inventors from India, China, Great Britain and Canada.[319] German founders are especially active in ICT, biotechnology and R&D services. They make up the seventh-largest national group among the high-tech start-ups in Silicon Valley.[320] Only two out of 100 patenting German inventors are active in the US. However, for every 100 newly founded high-tech companies in Germany, there are on average four to five new high-tech companies founded by Germans in the US.[321] Conversely, this means for Germany as a location for innovation, that precisely those mobile (patenting) inventors outflow who successfully translate their ideas into innovation, value added and jobs, and who benefit from more favourable framework conditions for start-up businesses in the United States.

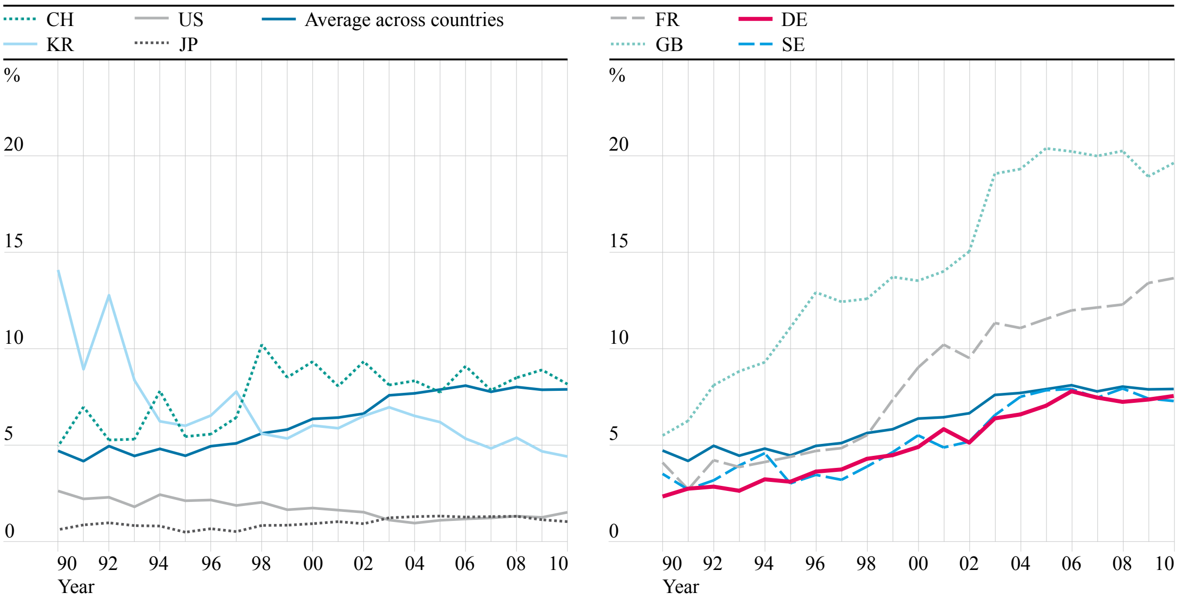
According to a recent study, MNEs applied for more than 80 percent of patents by mobile inventors in the base year of 2000.[322] Just under 20 percent of the patent applications were from SMEs.[323] If one accounts for size effects of patenting, inventors in SMEs are generally more mobile than inventors in MNEs, i.e. at 8 percent, mobile inventors are responsible for a higher proportion of all SME patent applications (compared to 6 percent for MNEs). Although MNEs apply for many of the patents by mobile inventors, inventors tend to leave their existing employer, rather than moving to an R&D site abroad within the same company.[324] More precisely, this means that around two thirds of mobile inventors switch to a different company or to a different research institution abroad, while the remaining third remain within the company when moving abroad.[325]

Furthermore, different mobility patterns for the various industries are identifiable. In 2009 the highest proportion of mobile inventors moving abroad were from the German pharmaceutical and biotechnology industry, as well as from the communications engineering industry (more than 10 percent respectively).[326] These industries also show an especially high level of migration from the previous company. In contrast, mechanical engineering is characterised by

Outflow rates of patenting inventors in international comparison between 1990 and 2010

FIG 24

DATA DOWNLOAD



Source: own depiction based on WIPO (2013).

a relatively low overall level of outflows paired with a high-level of intra-firm migration.[327] Thus the mobility patterns freeze Germany's existing specialisation profile for research and development. Technology fields and industries in which Germany is strong display a low level of inventor outflows over time, which, in addition, tend to be intra-firm.

If outstanding inventors can only be kept in those fields where Germany is already scientifically strong, then it is to be feared that additional investment in education and training designed to close gaps in Germany will be less effective than expected. There is a danger that many of the well-educated inventors will be lost again as a result of international mobility. Consequently, additional investment in education and training must be sufficiently concentrated and strong to create a new technology field that can compete internationally.

High outflows of German patenting inventors to foreign public research institutions

As highly qualified and highly productive scientists at universities and research institutions – including academic spin-offs – are very important for Germany as a science and innovation location, we take a closer look at the outflow of patenting scientists to foreign public research institutions. According to a study,[328] the outflow rate of German scientists employed in foreign public research sectors was 13 percent between 2001 and 2010. In comparison, the outflow rate of US scientists working at foreign public research institutions is only just under 2 percent. Consequently, the US and other European countries successfully retain patenting scientists at domestic public research institutions.[329] At the same time, Germany as a science location loses a relatively high number of top patenting scientists, in particular due to outflows to the excellent scientific systems in the US, Switzerland and Great Britain.[330]

However, the outflow of patenting German inventors does not necessarily lead to a shortage or constitute a brain drain, if it is offset by a corresponding level of inflows, i.e. brain gain. This will be examined in the following section.

Germany shows a low inflow rate of patenting inventors and a weak overall position

In international comparison, inflows to Germany are at best in the middle field, with a slight upward trend. If one examines the total sum of those inflowing to and outflowing from Germany, then Germany is well integrated in the international brain circulation. Yet, in comparison to other OECD and BRICS countries, Germany is only ranked in the lower third with a slightly negative net position of inflowing and outflowing inventors. With respect to its relatively moderate outflow rate, the German company sector is considerably more successful at keeping inventors in Germany when compared to the German public research system.

Again, the situation is considerably better in the United States. While according to the WIPO study (2013) the share of foreign inventors of all patentees in Germany for the period between 2001 and 2010 was around 5.5 percent, in the United States foreign inventors made up more than 18 percent in the same period. There are also clear differences between Germany and the US in respect of the inventors‘ countries of origin.[331]

Foreign inventors can also be identified at firm level. The proportion of foreign inventors amongst the top ten German patent applicants (both companies and research institutions), was generally in the single digit range across industries (between ca. 2 percent and 8 percent; cf. Table 8), and thus very low in international comparison. In the case of patented inventions in companies and research institutions in the USA, Switzerland or Great Britain the proportion of foreign inventors was considerably higher, often more than 50 percent, with Switzerland again in the forefront. As a consequence, German companies miss out on considerable innovation potential which companies in other countries are acquiring through the recruitment of foreign inventors and a corresponding increase in diversity (cf. Chapter B 4).[332] In the view of the Expert Commission, there is room for considerable action on the part of companies in this area.

Finally, if one compares the inflows of patenting inventors in major OECD countries between 1990 and 2010, country-specific trends can be identified (cf. Figure 25). While Japan has attracted hardly any foreign patenting inventors over time, the US and Switzerland have succeeded in continually extending their leading positions. Germany is ranked in the bottom group of the comparison countries with respect to the inflow of patenting inventors. Yet, along with Great Britain and Sweden, Germany has shown an upward trend since the middle of the 1990s. However, this upward trend is below the average increase in this sample of countries.[333] Amongst the selected OECD countries, the only ones that showed above-average increases were those that already had the highest inflow rates for inventors. Thus the gap between Germany and these countries has widened even more since 2000.

In turn, the inflow rate for foreign inventors entering the German public research sector is especially low. In Germany the rate for these inventors was ca. 8 percent for the period between 2001 and 2010. In comparison, it was 25 percent in the US and 48 percent in Switzerland. In contrast, France and Sweden with a rate of 7 and 10 percent respectively, are at a similar level as Germany.[334]

If one considers the net position of all inflowing and outflowing patenting inventors, then Germany has a negative balance over the past decade: there were around 7,000 more outflows from Germany than inflows into Germany. In an international comparison of OECD and BRICS countries, Germany as an innovation and science location is ranked in the bottom third with respect to its net mobility position (cf. Figure 26). Therefore, Germany ranks poorly compared to the leading countries Switzerland and the United States.[335] In addition, Japan and many smaller European countries such as the Netherlands, Sweden, Belgium or Finland also show balanced or positive net mobility patterns. This shows that Germany, as an innovation and science location, needs to improve its capacity for recruiting and keeping foreign patenting inventors.[336]

However, the “turnover” of mobile inventors in Germany, i.e. the sum of inflows and outflows (brain circulation) is the highest worldwide behind the United States. This at least points to Germany‘s tight integration into the international knowledge and know-how circulation. That said, it appears that too few mobile inventors actually choose to stay in Germany. Arguably, Germany at least benefits from indirect innovation effects as a frequent destination and

Share of foreign inventors among the top 10 PCT patent applicants of companies and research institutions in selected countries between 2006 and 2010

TAB 08

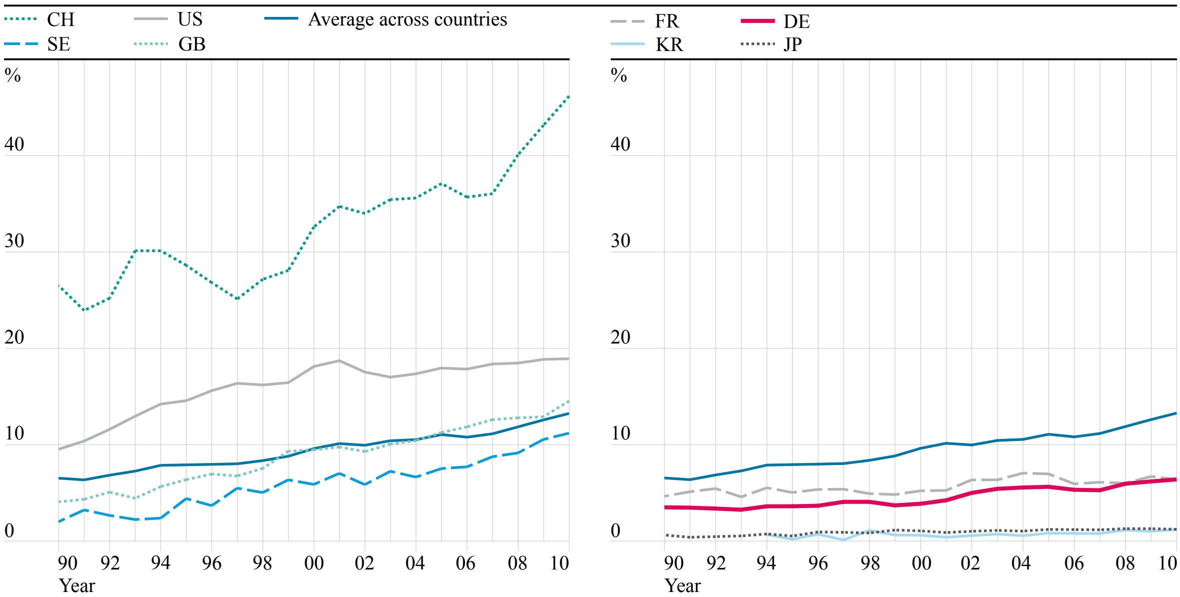
DATA DOWNLOAD

	Share of foreign inventors	PCT applications	PCT inventors
DE			
Robert Bosch	2.8	6,480	17,484
Siemens	6.4	4,555	11,753
BASF	14.4	3,562	15,427
Bosch-Siemens Hausgeräte	3.2	1,679	4,575
Fraunhofer-Gesellschaft	5.4	1,532	5,521
Continental Automotive	8.6	1,337	3,447
Henkel	6.4	1,210	4,420
Daimler	3.8	1,196	3,601
Evonik Degussa	5.6	974	4,103
ZF Friedrichshafen	2.4	958	2,702
US			
Qualcomm	50.8	6,528	19,907
Microsoft	57.4	3,020	11,297
3M	11	2,577	8,852
Hewlett-Packard	18.6	2,360	6,114
E.I. Dupont De Nemours	17	2,118	5,916
IBM	21.4	2,006	6,854
University of California	28.2	1,754	5,598
Motorola	23.4	1,573	4,488
Procter & Gamble	10.2	1,540	4,953
Baker Hughes	12.8	1,461	3,552
CH			
Nestlé	56.4	619	1,781
F. Hoffmann-La Roche	46.6	564	1,385
Novartis	62.6	489	1,179
Syngenta	66.6	308	972
Actelion Pharmaceuticals	30.2	272	879
Alstom	67.6	212	506
ABB	65	201	529
Swiss Federal Institute of Technology	49.2	186	534
Sika	30.4	179	426
Inventio	23.6	174	338
GB			
Unilever	10.4	594	1,536
GlaxoSmithKline	12.6	409	1,590
British Telecommunications	20.2	389	861
BAE Systems	3.2	305	644
Imperial College	29.8	246	648
University of Oxford	29.8	242	618
Dyson	10.4	237	579
Astrazeneca	8.2	210	640
Cambridge University	36.6	205	572
QinetiQ	2.2	185	458

Source: own depiction based on WIPO (2013:27).

FIG 25 **Inflow rates of patenting inventors in international comparison between 1990 and 2010**

DATA DOWNLOAD



Source: own depiction based on WIPO (2013).

country of origin for mobile inventors. Yet, whether the sum of direct effects (high outflow rate) and indirect effects (high knowledge circulation) is positive or negative at large cannot be determined on the basis of the conducted descriptive analysis.

With respect to a qualitative assessment of inventor mobility in Germany, there is clear evidence on a self-selection process of the best German patenting inventors into public and private research institutions abroad, to the detriment of Germany. This applies in particular to German patenting inventors who decide to found a high-tech company in the United States or self-select into the US science system. At the same time, this trend is not counterbalanced by a positive self-selection of inflows to Germany. Comparatively few highly-qualified inventors intending to found a company move to Germany from abroad. Similarly, few patenting inventors move to German research institutions.

DIRECT AND INDIRECT EFFECTS OF THE INTERNATIONAL MOBILITY OF SCIENTISTS AND INVENTORS ON RESEARCH AND INNOVATION CAPACITY

B 2–4

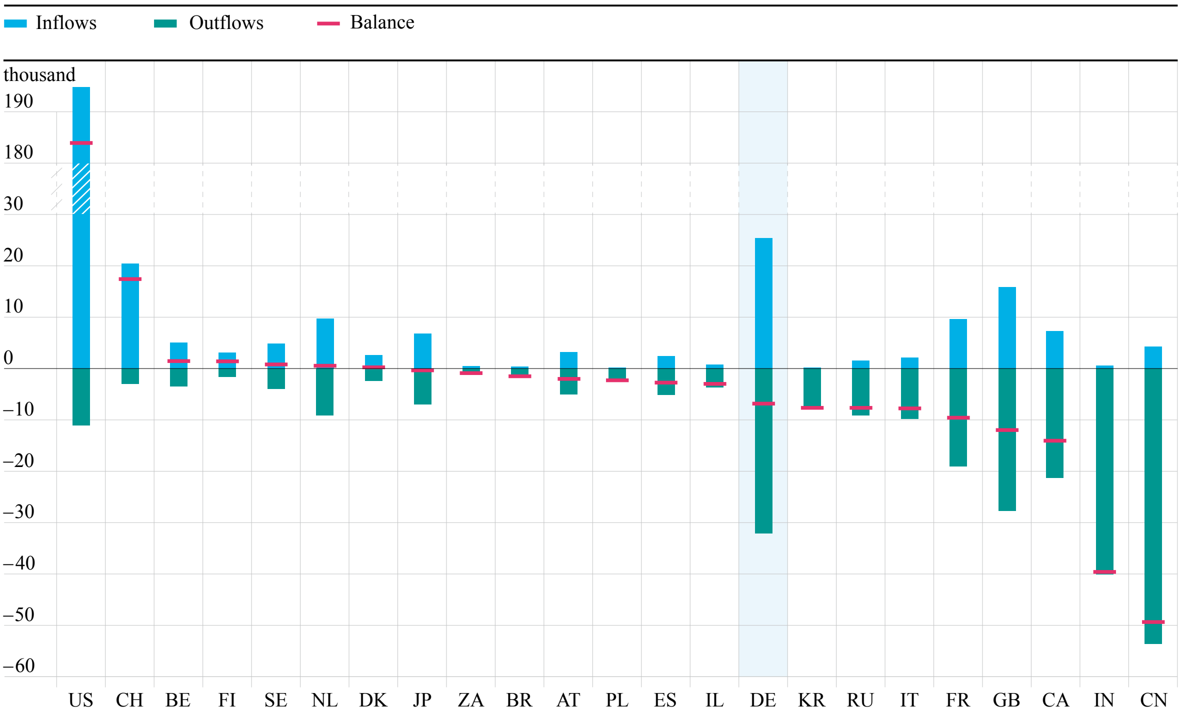
Direct effects of the mobility of scientists are generated by changes in the knowledge pool as a result of inflows and outflows. Indirect effects can occur if scientists remaining in the country, keep in contact with colleagues who have migrated. For the scientists remaining in the country this leads to an improvement of personal networks and participation in the international knowledge pool, enabling them to become more productive. If such indirect effects are large, then the negative impact of migration is less strong than expected.[337]

International mobility can thus affect a country‘s innovation capacity through numerous channels. A comprehensive analysis of the literature[338] uncovers three effects of international mobility: First, the positive selection of inflows plays an important role with respect to the direct effects, whereby the attraction of “star scientists” is decisive.[339] Second, innovation capacity can be improved directly through an increase in the diversity of scientists. Third, a

FIG 26

Inflows and outflows of patenting inventors between 2001 and 2010
(figures in thousand)

DATA DOWNLOAD



Sorted by balance in descending order.
Source: own depiction based on WIPO (2013).

How to read: approx. 25,000 inventors were inflows to Germany, while approx. 32,000 inventors were outflows. Germany thus has a negative balance of approx. 7,000 individuals.

so-called "diaspora network effect" can have an indirect positive influence: through close contacts between scientists in the home country and those who have migrated abroad, international information and communication costs can be substantially reduced. This network effect enlarges the knowledge pool and increases the likelihood of innovations.[340] Conversely, the outflow of knowledge is likely to generate corresponding negative effects.[341]

Empirical evidence, in particular that relating to indirect and longer term effects, is relatively sparse and methodologically extremely heterogeneous,[342] however it is possible to extract a number of stable patterns.

Positive direct effects of scientist mobility on the United States' knowledge pool

In the US, the inflow of foreign scientists de facto enlarges the knowledge pool without a displacement of native scientists.[343] The inflow of scientists leads to a disproportionate increase in the number of patents in the United States.[344] Hence inflows do not simply substitute patenting by natives, but they induce additional patenting.[345] Furthermore, evidence shows that scientists inflowing to the US apply for twice as many patents as native scientists and that foreign college graduates lead to a doubling of patents in the respective regions.[346] The great significance of foreign scientists or inventors is also underlined by the finding that around one in eight of the world's most frequently cited scientists (1981–2003) were born in a developing country, however 80 percent of them migrated to a developed country – often the US – during their career.[347] Thus in the USA the research and innovation knowledge pool is systematically enlarged as a result of the high level of immigration.

Negative direct effects of scientist mobility on Germany's knowledge pool

A historical study[348] examines the research performance of German universities affected by Jewish emigration during the period of National Socialism. The study shows that the primary cause of the deterioration in Germany's research performance at that time was the loss of top scientists, whereas the destruction of university buildings during the Second World War played a much smaller role.

As a current indicator for the loss of research capacity the country of the hosting institution and the nationality of scientists funded by the European Research Council (ERC) can be employed as an indication for the loss of research capacity due to migration.[349] This shows that while German researchers are highly successful in acquiring ERC grants, German researchers at the same time acquire by far the highest number of grants while employed at institutes abroad (221) (with Italy in second place with 143 grantees hosted abroad; all other countries have an average of around only 30 grantees hosted abroad). Here Germany at least temporarily loses substantial research potential.

Strong indirect effects of scientist mobility in the USA and also to a reduced extent in Germany

Historical studies also examine the indirect effects of the displacement of Jewish and politically undesirable professors on the publication success of their doctoral students who remained in Germany.[350] They show that the outflow of the best scientists during the period of National Socialism, i.e. in a situation in which it is unlikely that there were any systematic network ties with the home country, had a strong negative affect on the productivity of the researchers remaining behind. However, this finding does not exclude the possibility that international networks could have a dominantly positive effect in a situation where a regular exchange between movers and stayers is easily possible.

If one uses co-authorship as an indicator for such network effects, then in the case of the most frequently cited publications of international co-author teams worldwide, it can be observed that the corresponding authors of co-author teams – and thus often the most important or decisive authors – are most frequently residing in the US.[351] This indicates the importance of good networking with co-authors residing in the United States. To this extent, networks between scientists who migrated to the US and their former colleagues have a clear potential for positive spillovers, with benefits for those scientists that remained in the home country, but also for those returning. For example, Switzerland's international publication patterns provide evidence on the large importance of such international researcher networks. Compared to other countries, Switzerland has the highest number of frequently-cited publications as a proportion of all publications, however almost half of the corresponding authors live abroad. The impact of the scientific output can be systematically increased through cooperation in international networks, in particular when partnering with authors in the US.

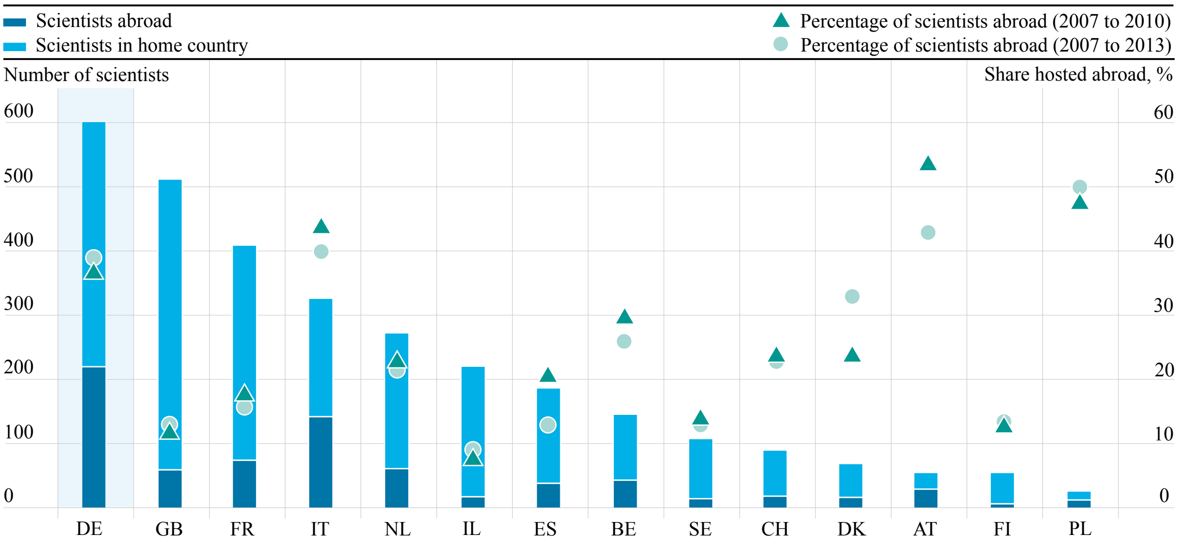
Indirect effects resulting from the knowledge flows between home and abroad can also be demonstrated in the case of inventors, namely on the basis of the joint patenting by inventors in Germany and inventors of German origin abroad. Here Germany performs well in international comparison: teams composed of German inventors abroad and inventors in Germany are responsible for around one quarter of all PCT patent applications.[352] In international comparison, only US inventors abroad have a greater tendency to exchange knowledge with inventors in their home country and submit joint patents.[353]

In conclusion, an assessment of international mobility of scientists should not only account for the net position as regards inflows and outflows of scientists, i.e. the relationship between brain drain and brain gain, but also for the positive network effects resulting from brain circulation. Outflows, particularly of top scientists, result in a loss of German research capability. Nevertheless, national research can be strengthened to some extent through positive network effects and greater integration in international knowledge circulation. However, Germany still has ground to make up in this area – for example in comparison to Switzerland. The

FIG 27

Nationality of grantees funded by the European Research Council between 2007 and 2013

DATA DOWNLOAD



Source: own depiction based on EFI (2011); calculations according to EU-ECORDA database.

How to read: between 2007 and 2013, approx. 600 German scientists received ERC funding (left axis). From among these scientists, nearly 400 performed their research in Germany, and more than 200 performed their research abroad. The share of scientists hosted at foreign research institutions is nearly 40 percent (right axis).

strengthening of indirect effects – again, as exemplified by the Swiss case – requires a strong scientific base and an attractive science system in the home country, as these facilitate the best possible interaction with the global science system.[354]

However, whether in sum the positive network effects are sufficiently large to compensate for the direct negative effects of outflows from Germany cannot be answered on the basis of the very sparse empirical evidence. Yet, it can be concluded that Germany's innovation capacity increases when its science and research system is made more attractive, especially to top scientists, thus strengthening the direct and indirect positive effects of researcher mobility. Therefore, the decisive question is what motivates the best scientists to leave their own country or migrate to another country, respectively.

REASONS AND BARRIERS FOR THE INTERNATIONAL MOBILITY OF SCIENTISTS AND INVENTORS

B 2–5

Excellence of the science system as the most important factor

The most important reasons for international mobility of scientists are academic motives: "... a dynamic, well-funded science system seems to trump all other incentives."[355] This is especially confirmed in a comparison between Germany and the United States.[356] Surveys among natural scientists[357] provide detailed information on the most important factors for international mobility: improved career opportunities, cooperation with outstanding colleagues and research teams, the excellence of the foreign host institution in one's own research field as well as better infrastructure and faculties (cf. Figure 28).[358]

Above all, scientists are internationally mobile in order to gain better access to leading scientists in their field, to the best research centres or to important networks. This explains the leading role of the United States, as well as Canada, Great Britain and Switzerland as destination countries: as Figure 29 shows, scientists in the US (2003 – 2011), who are often chosen as co-authors by foreign scientists, have the highest publication productivity, measured in terms of the annual number of articles (as indicated by the size of the circle). Furthermore, they also display a very high average impact factor (as indicated by the high vertical position of the circle).[359] However, as there is also a large number of publications in the US produced without foreign co-authors, – primarily a consequence of the size of the home market – the proportion of international co-publications is rather low (as indicated by the position of the circle relatively far to the left).

Canada and Great Britain have an impact factor that is almost as high as that of the US, however, they have a relatively high proportion of publications with international co-authors (as indicated by the position of the circle further to the right), which is an indirect consequence of smaller home markets. In contrast, Germany with its less favourable international mobility patterns than the US, Canada or Great Britain – as shown in the previous section – has approximately the same number of publications (size of the circle) and a slightly higher share of international co-publications (position of the circle to the right) compared to these countries, but a significantly lower impact factor (lower position of the circle).

The situation is strikingly different in Switzerland or the Netherlands where – as shown in the previous sections – mobility patterns are considerably more favourable than those in Germany. Both countries have a far above average impact factor – albeit based on a very small number of publications. This is accompanied, especially in Switzerland, by a very high level of international cooperation, which appears to leverage the impact of these publications. Favourable international mobility patterns are exhibited by those countries where the best scientists, i.e. the best scientific research environments are to be found. Thus the primary goal of internationally mobile scientists, of migrating to locations with excellent research conditions, generates a self-reinforcing process.

Working conditions and personal motives are important but secondary causes of international mobility

The aforementioned survey results[360] clearly show that only after a large number of academic motives other motives for international mobility are mentioned. These include the attractiveness of the lifestyle in the destination country, the better quality of life, better working conditions such as vacations or working hours, or family and personal motives. According to this study, access to third-party funds and monetary or non-monetary compensation packages (wages, corporate social benefits etc.) have a relatively low priority. One possible reason for this low priority is that relatively generous endowments and compensation packages are taken for granted in the typical destination countries of internationally mobile scientists. This assumption is confirmed by empirical studies which show a strong correlation between research budgets and inflowing researchers[361] or between wage differentials and international mobility.[362]

Legal restrictions on residency and cultural barriers reduce the attractiveness of Germany as a destination for internationally mobile scientists

Beyond this, internationally mobile scientists are naturally also migrants like any other, and they struggle with the same problems. These range from obtaining a visa and integrating children into a foreign school system to occupational opportunities for partners and overcoming cultural differences. Here public policy can assist in facilitating the international mobility of scientists through transparent and immigration-friendly immigration policy. These should include straightforward visa and working conditions for scientists and their families[363] and could include financial subsidies or other integration and moving allowances or relocation services.[364]

Germany’s current visa regulations are often perceived as a bureaucratic hurdle, although they hardly represent a barrier for today‘s mobile scientists (cf. Box 11).[365] However, the complexity of visa regulations and the range of administrative institutions involved prevent an optimisation of the statutory regulations and their application. More user-friendly and simpler

Reasons for international mobility of scientists

FIG 28

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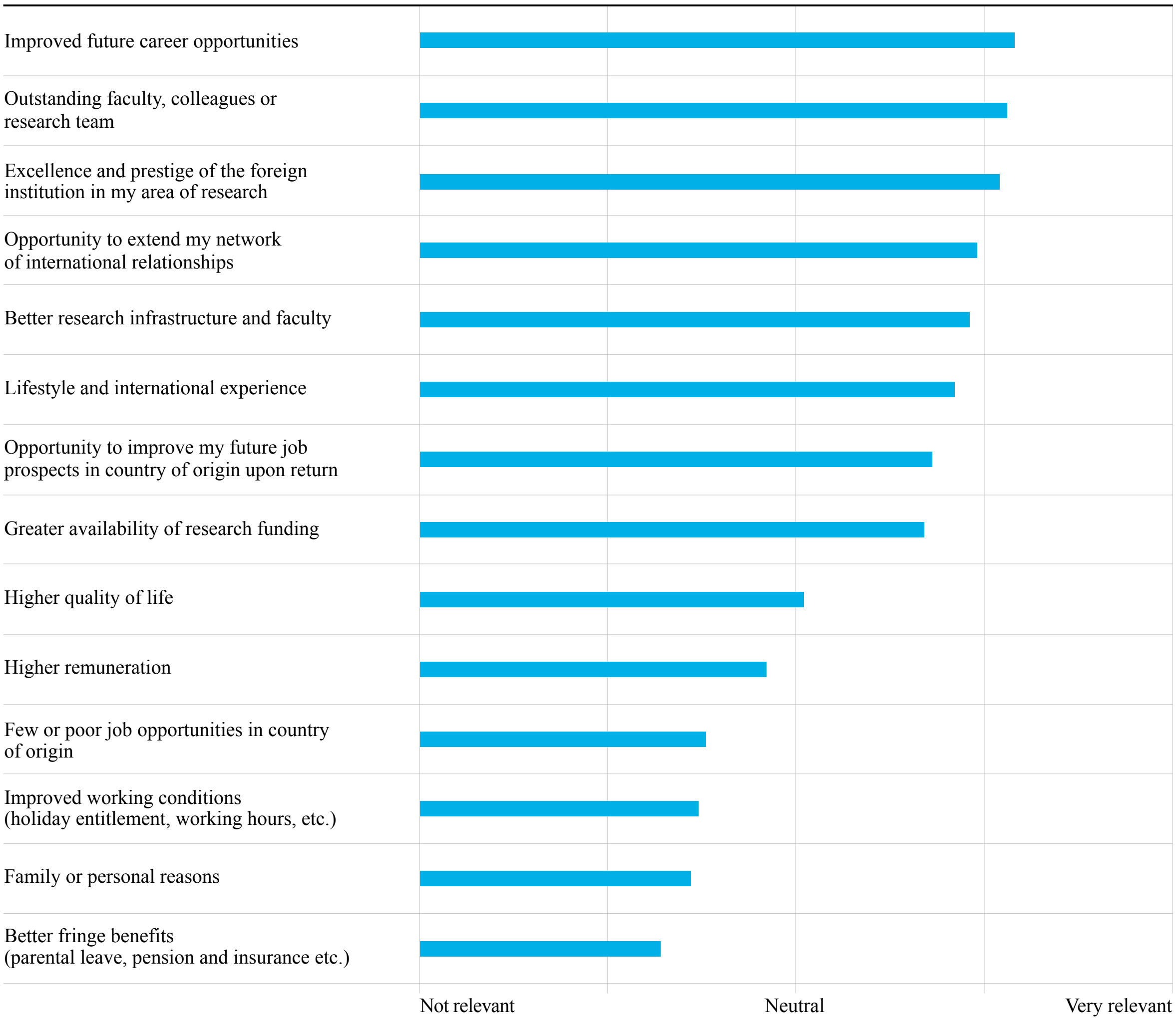

Source: own depiction based on Franzoni et al. (2012a).

processes are indispensable if immigration is to be made more attractive to foreign scientists. The EU Blue Card has had a positive effect in this context. Only recently introduced, it has already become an extremely attractive residence permit for newcomers. With around 2,500 awarded permits within one year (end of 2012 to end of 2013), it has brought more academically qualified workers to the country than any previous residence permit for this target group. Between 2005 and 2012, under the former provisions for highly qualified workers (clause 19 of the *AufenthG*), only a total of 2,796 persons immigrated and are still resident in the country. The Blue Card reached this figure within less than a year and is considered a step in the right direction.

The organisational structures of the German research system often present a barrier for returnees

For those returning from abroad the situation is different. Visa regulations or integration problems present no or hardly any barrier. Family and personal reasons are often the primary motive for returnees. In contrast, organisational structures in the German

FIG 29 **International scientific collaboration and impact of scientific publications between 2003 and 2011**

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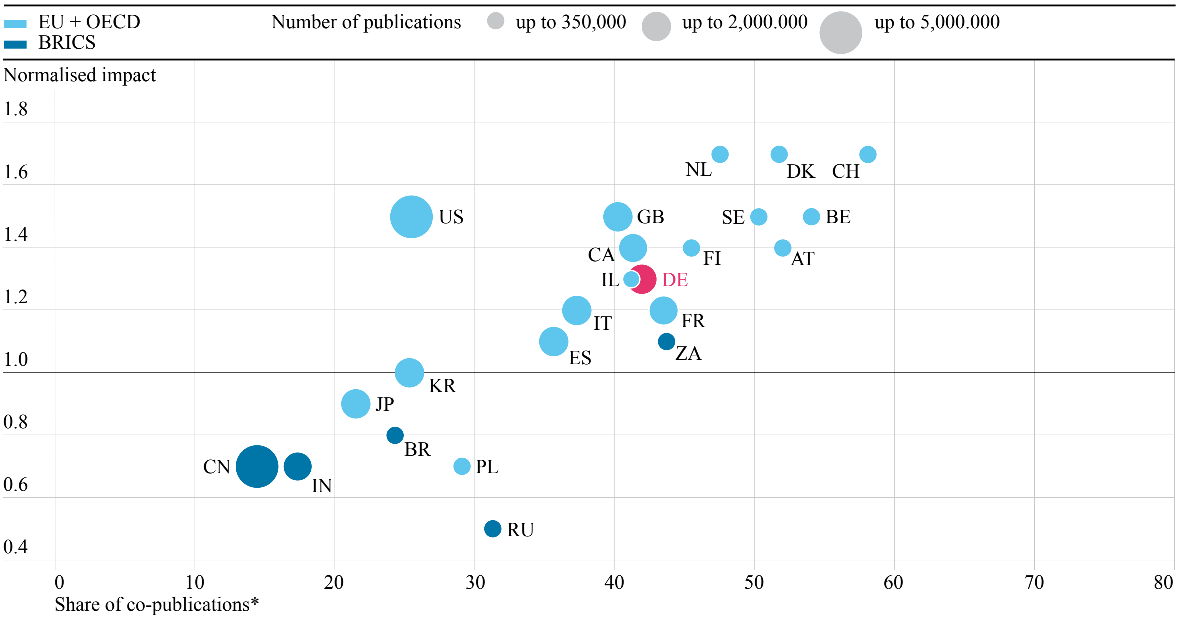

Source: own depiction based on OECD (2013b: 6).
* including foreign co-authorship in all publications of national research organisations

How to read: Germany has a relatively high number of total publications (size of the circle) and occupies a similar position in its share of international scientific collaborations (position of the circle to the right). Yet, Germany's impact factor is significantly lower (lower vertical position of the circle).

research system or incompatible social security systems and family policies frequently represent barriers.[366] The causes and barriers for returnees thus differ from the general motives of international scientists. If one simply aims to bring back Germans to Germany, then it may be possible to achieve a great deal with only a few organisational measures.[367] However, if one wants to benefit from the mobility of all of the best international scientists, then this requires large-scale investments to strengthen the German science system and to create internationally visible fields of excellence. In turn, this will also facilitate the return of the best German scientists abroad. To create an internationally visible site of research excellence, the goal should be to create a research infrastructure that is strictly directed towards excellence, which provides the necessary freedom and flexibility for the recruitment and integration of top international scientists – instead of focussing on the needs of a large and strong middle field. Naturally, generous financial resources (basic funding, third party funds and compensation packages) are needed, however, dynamic organisations and flexible systems of financing are also important.[368]

RECOMMENDATIONS

B 2–6

Today more than ever, science is conducted within a competitive international environment in which countries with highly developed, financially well endowed and dynamic research systems lead the field. Scientists and inventors migrate to those locations where research conditions and financing are especially attractive. The best, most talented scientists are attracted to the best colleagues in their field worldwide. This leads to self-reinforcing effects. To break through them, massive countermeasures are required. In order to improve Germany's position in the international competition for the best scientists and inventors, and to benefit more strongly from their mobility, it must systematically and comprehensively expand and develop its research system's existing strengths so as to create internationally competitive research and working conditions in the leading segment.

This will also alleviate some of the problems for research in the university medicine sector as discussed in Chapter B 1 and facilitate the strengthening of the

ICT industry as called for in Chapter B 3. In order to increase the competitiveness of the German research system in the leading international segment, the Expert Commission recommends ensuring good basic funding and excellent project financing opportunities. At the same time, organisations within the top tier must be granted more freedom to experiment with new personnel or budget structures, and thus keep pace with international developments.

In addition, Germany must intensify efforts to attract international research talent to Germany and retain the best scientists in the country. The Expert Commission recommends undertaking greater efforts to attract young foreign scientists in the post-doctoral, but also in the doctoral phase to Germany, and to offer the best of them attractive conditions for a future stay in the country. As recommended in the 2012 Report, increased efforts also need to be made to attract outstanding foreign students on the Bachelor or Master level and convince them to take up employment in Germany following graduation.[369]

To simplify the employment of foreign doctoral candidates within the framework of the existing wage structure, the Expert Commission recommends reducing the minimum income requirement for residence permits granted in accordance with clause 20 of the *AufenthG*. Furthermore, applying for residence permits should be made easier to understand and more user-friendly. In addition, the general public and interested foreign scientists should be better informed of the current, improved options for obtaining residence permits for scientists. This should counteract the widespread perceptions regarding potential bureaucratic hurdles.

Furthermore, efforts need to target the return of top German scientists and inventors working abroad. “Pooled appointments” – e.g. recruiting entire groups of scientists, can quickly provide these returnees with an attractive research environment. This would be especially advantageous in strategically important scientific disciplines and future core fields where a significant leap forward could be achieved by appointing renowned research groups.

The effectiveness of existing returnee programmes should be systematically evaluated. After a careful evaluation, they should be expanded and strongly focussed on attracting leading scientists. In addition to excellent research conditions, personal mobility requirements for both well-established and young foreign scientists also need to be addressed if they are to be motivated to work in the German science system. “Dual career” issues are becoming increasingly important and must be given greater attention during both the development of visa regulations and the targeted recruitment of top talent. Furthermore, efforts need to be made to increase the compatibility of social security systems for researchers and scientists across Europe as the existing differences hinder cross-border appointments and mobility.

In order to be able to identify new trends in the international mobility of scientists and inventors at an early stage, the Expert Commission recommends a systematic monitoring of brain drain and brain gain.[370] In addition, an “opinion barometer” which regularly records the mood amongst leading scientists (foreign and domestic scientists in Germany and in important competing countries) could help to identify problems and the need for action at a very early stage.

B 3 STATUS AND DEVELOPMENT PROSPECTS OF ICT IN GERMANY

Information and communication technologies (ICT) are of central importance for the innovation system and social and economic development of the Federal Republic of Germany. The ICT industry and its associated services sectors are a cornerstone of the German economy and are also closely interlinked with other industry sectors. The market volume of Germany's ICT industry currently amounts to EUR 126 billion and continues to grow further.[371] The ICT sector is one of the most important sectors of the German economy. However, due to its heterogeneous structure, it is less visible than other core sectors of the economy.[372] A high proportion of professionals working in ICT companies are highly qualified. The ICT industry is very research-intensive and is characterised by particularly high innovation dynamics.

ICT as an important general purpose technology

Even more important, though, are the indirect effects of the ICT industry and ICT technologies on other sectors of the economy. ICT has all the characteristics of a general purpose technology (GPT, cf. Box 12) and therefore gains particular relevance.

Important key areas of the German economy critically depend on the latest applications of ICT technologies. ICT facilitate the development of new products and services and new organisational forms and are thus essential for safeguarding Germany's competitiveness.[373] Examples include:

– Future production systems: The process of digitalisation dramatically changes organisational structures and production chains. The application of information technology will have a sustainable impact on mechanical engineering, automation technology and also automotive manufacturing in Germany.
– Future mobility: An ever-increasing proportion of vehicle-related value added is attributable to information technology and electronics. The optimisation of transport systems and traffic flows increasingly depends on ICT and networking.
– Future energy system: Germany's Energy Transition relies on the use of the latest ICT and complex organisational models such as smart grids or green ICT.
– Innovative medical systems: The combination of bioinformatics, genetic engineering and medicine is sustainably changing therapy methods and medical care systems (cf. Chapter B 1).
– Trade, distribution and logistics: Large segments of the service economy are significantly influenced by the latest ICT (e.g. e-commerce, customer information systems, etc.).

The dynamics of innovation in these areas of application crucially depends on a close interaction between users, ICT manufacturers and specialist ICT service companies.[374] All of these parties are required to conduct R&D projects in a cooperative manner. Especially in the area of digital technologies, the concept of an interlinked "open innovation" is widely accepted. In fact, a close vertical collaboration between ICT suppliers and ICT users is a key requirement for success. In addition to vertical information externalities, there are strong horizontal spillover effects between an industry's early users of the latest

BOX 12

General purpose technologies (GPT)

Economic literature stresses the importance of general purpose technologies (GPT) for economic growth, productivity and employment.[375] These include cross-cutting technologies with a very high productivity effect on a variety of economic sectors. General purpose technologies have four common characteristics:

1. They can be used productively in a variety of applications.
2. Prices and performance features of the technology change greatly over time.
3. General purpose technologies facilitate subsequent innovations for numerous products, processes and business models.
4. There are strong correlations with other, complementary technologies and subsequent developments.

TAB 09 **Classification of ICT sector according to European Information Technology Observatory (EITO)**

ICT sector according to EITO classification	
	IT services
	Software
	Telecommunication services
	IT hardware
	Telecommunication equipment

Source: own depiction based on EITO (2013).

information technologies and companies that learn from the experience gained by these early adopters. These companies are further improving their ICT systems and adapting them to their organisational models, respectively.

Germany's capacity for innovation crucially depends on the dynamic organisational skills in the use of the latest ICT. The central questions are as follows: What are the structural conditions and what are the policy measures required for ensuring that key areas of the German economy are further expanding their competitive advantages through the early and effective use of new information and communication technologies? Will it suffice to largely rely on ICT technologies and products developed abroad? Or will it be important for Germany to have its own strong ICT production sector and associated ICT service providers? In the view of the Expert Commission, the importance of spillover effects and geographic proximity in the innovation process calls for a highly developed national ICT provider structure at least in key areas. This will be explained in more detail below.

Strong impact of ICT on growth and productivity

Given the special characteristics of general purpose technologies as described above, investments in the development and use of digital technologies have a strong influence on growth and productivity. Numerous recent studies have confirmed the effects of ICT investments on the productivity of individual sectors and on the national economy.[376] Particularly the high productivity growth in the United States between 1995 and 2005 has thus been attributed to an increased use of the latest I&C technologies.[377] This correlation has been documented not only in economic studies, but also in numerous productivity analyses at sectoral and company levels.[378] These studies have been reproduced in many other countries and have demonstrated the strong impact of various ICT user profiles on a country's competitiveness. Especially the productivity gap between the United States and Europe has been explained on the grounds of a higher intensity of ICT use in the United States.[379] Within the framework of the EU KLEMS Growth and Productivity Accounts, similar studies on productivity differences within Europe have been conducted since 2007.[380] These studies – as well as those conducted by the OECD – show that Germany's growth in labour productivity was relatively low between 2000 and 2009 and that ICT's effect on Germany's labour productivity is relatively low when compared with other countries.

Corresponding studies on the productivity effects of ICT investments in Germany are conducted at regular intervals.[381] The monitoring report of the BMWi shows that 22 percent of overall economic gains in labour productivity in Germany between 1995 and 2009 were attributable to investments in ICT.[382] Productivity effects were particularly high for business services and retail. ICT have a strong impact on individual sectors of the German economy; albeit the fact that their cross-sectoral impact on the overall economy is less pronounced than it is in other countries.

The structure of Germany's ICT industry

To analyse the structure and the international competitiveness of Germany's ICT industry, one needs to closely examine individual segments and their respective strengths and weaknesses. "ICT industry" or "ICT sector" is used as an umbrella term that includes both production sectors and service sectors. There are clear structural differences between the individual segments. While some of the economic sectors are dominated by large corporations and foreign enterprises, others tend to be characterised by medium-sized and domestic enterprises. The Federal Association for Information Technology, Telecommunications and New Media (BITKOM) recorded a market volume of EUR 126 billion for the ICT industry for the year 2012. Based on a broader classification of the ICT industry, the Federal Statistical Office and the BMWi recorded an annual turnover of EUR 222 billion in their Digital Economy monitoring report.[383] Based on the BMWi's classification, the ICT sector is one of the three most important sectors of the German economy. When measured in terms of revenue and employment, the ICT industry even outperforms mechanical engineering, the chemical industry and electrical engineering.[384]

Yet, despite its size, the ICT sector is less visible than other industries, which is also due to the heterogeneous structure of ICT companies. Germany's ICT industry is characterised by the following features:

- The ICT industry comprises both productive sectors and service sectors, with each having very different supply structures and development prospects.
- Several segments of the ICT goods production are exposed to stark international competition that is often characterised by high pricing pressure. As a result, German suppliers have reduced their capacities considerably over recent years.
- ICT services tend to have a higher development potential, but again there are significant differences between telecommunications service providers and IT service providers.
- Large parts of the ICT industry are characterised by fluid structures and entrepreneurship (e.g. software and internet companies), and their interests may differ significantly from those of large established companies.

Based on the development in the period 2000–2012, the following analysis outlines the areas in which structural deficits of the ICT industry have to be overcome in Germany, as well as potential starting points for promising future developments. A distinction is made between the following industry segments:
- IT services and software,
- telecommunications services,
- IT hardware, and
- telecommunications equipment.

Developments in the IT services and software segment

The market for information technology services and software continues to grow strongly in all countries and displays high innovation dynamics. Also in Germany, the market volume of IT services and software has increased significantly since 2000, reaching a value of EUR 52 billion in 2012.[385] The expansion of the IT services sector remained largely unaffected by the financial crisis. Between 2008 and 2011, the number of employees in the IT services sector increased by 115,000 to a total of 540,000.[386] This market segment offers the highest potential for the further development of the ICT industry in Germany. However, there are also structural deficits with regard to the growth and internationalisation of German IT service providers and software vendors. Many of the businesses are still dominated by SME structures and have only a limited international focus.[387] These companies largely focus their business on the German market, or mostly on other European countries in those cases where they do operate internationally.

Developments in the telecommunications services segment

Quite a different picture can be observed in the field of telecommunications services – a market segment that only grew by 3.5 percent between 2005 and 2012 (cf. Table 10).[388] It is important to distinguish between different groups of countries and market segments. While strong growth could be observed in telecommunications services in the emerging economies, the highly developed countries tended to stagnate. At the same time, landline-related services have been increasingly replaced by mobile services. In the highly developed countries such as the US, Japan, the United Kingdom and France, this has led to the fact that major telecommunications service providers lost in added value as a result of deregulation and substitution competition.[389] In spite of new enterprises and temporary growth among mobile service providers, the highly developed markets in this segment were still subjected to comprehensive restructuring processes. Also in Germany, the market volume of telecommunications services declined in the period 2005–2012. In addition, the introduction of process technologies and the associated increase in productivity have led to a serious reduction of labour. Between 2008 and 2012 employment in the field of telecommunications services in Germany was cut by 7 percent per annum to 86,400.

Developments in the telecommunications equipment segment

Even more clearly than in the services sector, Germany has lost ground in international competition in the telecommunications equipment segment. The world market for telecommunications equipment was characterised by high growth and high innovation dynamics overall. Between 2005 and 2012 the global market volume rose by 8.3 percent per annum, reaching a value of EUR 395 billion. Especially the emerging Asian economies displayed double-digit growth rates in this segment (e.g. China 18.1 percent, India 14.8 percent). The German market for telecommunications equipment, however, grew by only 3.5 percent per annum. With a volume of EUR 12.6 billion in 2012, it accounts for a mere 3.2 percent of the world market.

The production and development of telecommunication devices has increasingly shifted towards Asian countries. These are putting established manufacturers in highly developed countries under pressure through low costs. Especially the German communications engineering industry has been heavily affected by this. As a result, German device manufacturers and suppliers have been successively withdrawing from this market since 1995. Manufacturers of telecommunications technology equipment and facilities have therefore been exposed to comprehensive restructuring processes and substantial job cuts. Up until the 1990s, German companies such as Siemens AG or Robert Bosch GmbH had been technological leaders in this field. However, in the course of digitalisation, these companies lost their leading position with regard to the latest generations of telecommunications technology. Between 2000 and 2012, Germany recorded significant reductions in value added and employment. Today, the telecommunications equipment segment employs no more than 45,800 people.

Developments in the IT hardware segment

The market for IT hardware was globally characterised by particularly high innovation dynamics and a pronounced trend to relocate production sites. Overall, the world market for IT hardware grew at an annual rate of 4.2 percent between 2005 and 2012, reaching a volume of EUR 360 billion. There were pronounced differences between the highly developed countries and the emerging economies. The market for IT hardware grew by 2.1 percent per annum in the United States, and by 1.6 percent in Japan. The EU market, however, experienced a downturn of 3.9 percent per annum.[390] In contrast, the BRIC countries recorded an average annual growth of 16.9 percent in the IT hardware market.

The IT hardware market was characterised by short product cycles in conjunction with sharp price cuts, whereby the world market was increasingly dominated by Asian companies. In Western Europe as a whole, and in Germany in particular, this resulted in major structural adjustments on the part of IT hardware producers. Initially, the market volume for IT hardware declined from EUR 28.9 billion in 2000 to EUR 21.3 billion in 2007. Exacerbated by the financial crisis, 2009 saw a further 42 percent decline to EUR 12.4 billion. In the subsequent years, Germany's IT hardware market failed to recover from the crisis. In nominal terms, today's market only achieves the level of the early 1990s (in 1991, the market volume for IT hardware amounted to EUR 13.3 billion). That said, IT hardware companies from Germany had never held a strong position on the world market. Thus the market comprised mainly niche suppliers, and even the remaining German manufacturers had largely abandoned their production since the onset of the financial crisis, if not earlier.[391] Foreign companies that had major, long-established production sites in Germany (e.g. IBM, HP, or Fujitsu), largely relocated their value creation in IT hardware to third countries. Between 2008 and 2012, employment in the field of IT hardware in Germany was cut by

TAB 10 **A comparison of growth rates for the ICT segments in the German market and the world market**

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	Market volume in Germany 2012	World market volume 2012	Growth in Germany 2005–2012	Growth in world market 2005–2012	Share of German market in ICT world market
	(billion EUR)		(percent)		(percent)
IT services	**98,478**	**1,977,201**	**0.0**	**4.1**	**5.0**
IT services	34,799	493,539	3.6	3.2	7.1
Software	17,254	285,921	4.7	9.7	6.0
Telecommunication services	46,425	1,197,742	–3.3	3.5	3.9
IT hardware	**27,446**	**755,034**	**–1.0**	**6.2**	**3.6**
IT hardware	14,855	360,162	–3.9	4.2	4.1
Telecommunication equipment	12,591	394,872	3.5	8.3	3.2
Total ICT market	**125,924**	**2,732,236**	**–0.2**	**4.7**	**4.6**

Source: own calculations based on EITO (2013).

13 percent per annum, with currently only 21,000 people employed in this segment.

In the course of the last decade, the ICT industry as a whole experienced a significant shift from the production sectors towards the services sectors. The value chains were reconfigured, and Germany saw an expansion of customer-oriented service sectors in particular. In parallel, the upstream process stages were relocated to sites abroad or were increasingly concentrated on those few remaining specialist areas in Germany. The depletion of value creation processes in the field of production also led to major changes in the area of research and development in the ICT industry.

Analysis of R&D expenditure in the ICT industry

Across the globe, the ICT industry is one of the economic sectors with the highest R&D expenditure and the strongest dynamics. The leading multinational enterprises active in R&D increased their R&D expenditure in both absolute and relative terms (as measured in relation to revenue or value added, respectively). In the ICT industry, competition is shaped by very high R&D budgets and subsequent patent protection. An increasing number of the world's most important R&D companies come from the United States and from Asia. Most of them continuously increased their R&D intensity, i.e. their R&D expenditure as a percentage of turnover, in the period 2000 to 2012.[392] However, this does not only apply to manufacturers of computers, semiconductors, and telecommunications equipment – sectors which have always been R&D-intensive. Software companies, IT service providers and internet companies are investing an increasing proportion of their revenue in R&D. In the services sectors, R&D expenditure is thus becoming more and more important relative to hardware development.

Germany's ICT industry only partially kept up with these international trends towards a strong increase in R&D investment and a growing R&D intensity among ICT service providers. In terms of R&D investment, Germany did not step up its efforts. Furthermore, the German ICT service providers did not develop as dynamically as comparable companies in other world regions. In Germany, R&D expenditure is still focussed on manufacturing companies – despite the fact that the remaining manufacturing companies have gradually lost importance. Cuts in production and employment frequently went hand in hand with a depletion of the corresponding domestic R&D.

R&D expenditure was significantly reduced in the area of telecommunications equipment in Germany between 2001 and 2011. With an internal R&D expenditure of EUR 1.1 billion, German companies can barely keep up with today's leading foreign suppliers. For instance, in 2011, Cisco was the only company to have an R&D budget of EUR 4.2 billion. Ten years ago, German telecom equipment manufacturers expended EUR 2.4 billion on R&D. It could be argued that even in 2001 this budget was too small to cope with the dynamic changes in terms of digitalisation and mobile communications. Since then, R&D expenditure has been reduced in several stages and companies started preparing their withdrawal from those business segments with the stiffest competition.

The IT hardware segment underwent a similar development: in 2011, Germany invested a mere EUR 600 million in R&D in this segment. R&D expenditure remained largely unchanged over the last ten years in Germany and focussed on a small number of specialist suppliers. Within the same period, the large multinational IT corporations continuously increased their R&D investments, and only few of them still maintain development activities in Germany.

Domestic enterprises on their part have been transferring their R&D efforts to other fields. For several years now, R&D in the field of data processing and peripheral equipment account for only 1.5 percent of the German economy's R&D expenditure. While IT-related R&D efforts are also required in other industries, these largely focus on ensuring competitiveness in the respective user industries, e.g. in automotive and mechanical engineering. IT innovations are mainly utilised in individual industries and companies but do not have the same broad effect as in other countries. Thus, Germany is not reaping the potential benefits of ICT as a general purpose technology that can penetrate broad application areas and facilitate the creation of new industries.

While an expansion of R&D activities could be observed in the service-related segments of Germany's ICT industry, the structural change towards service-related R&D is less dynamic than in other countries. On a more positive note, Germany at least increased its R&D expenditure in the field of ICT services. R&D expenditure in the field of IT services thus increased over the last decade, reaching a value of EUR 2.3 billion in 2011 (2001 reference value: EUR 1 billion). This is complemented by the telecom service providers' R&D expenditure, which amounted to EUR 570 million in 2011 (2001 reference value: EUR 769 million). Yet, these R&D efforts should only be assessed in relation to other countries' R&D investments and innovation strategies. Numerous countries systematically expanded their R&D investments in the ICT sector, thereby placing stronger emphasis on service-related innovations and new business models.

Overall, the ICT industry as an innovation driver plays a rather moderate role in Germany. Due to the lack of major players, Germany's R&D efforts do by no means reach the level that is typically reached by other countries. An analysis of the global distribution of R&D capacities confirms that Germany plays only a subordinate role in the ICT sector.[393] 33 percent of global R&D expenditure in the ICT sector is attributable to the United States, followed by China and Japan at 14 percent each, and Korea at 10.5 percent. Germany ranks only sixth just after Taiwan (cf. Figure 30).

FIG 30 **The leading countries' share in global R&D expenditure in the ICT sector 2011** (figures in percent)

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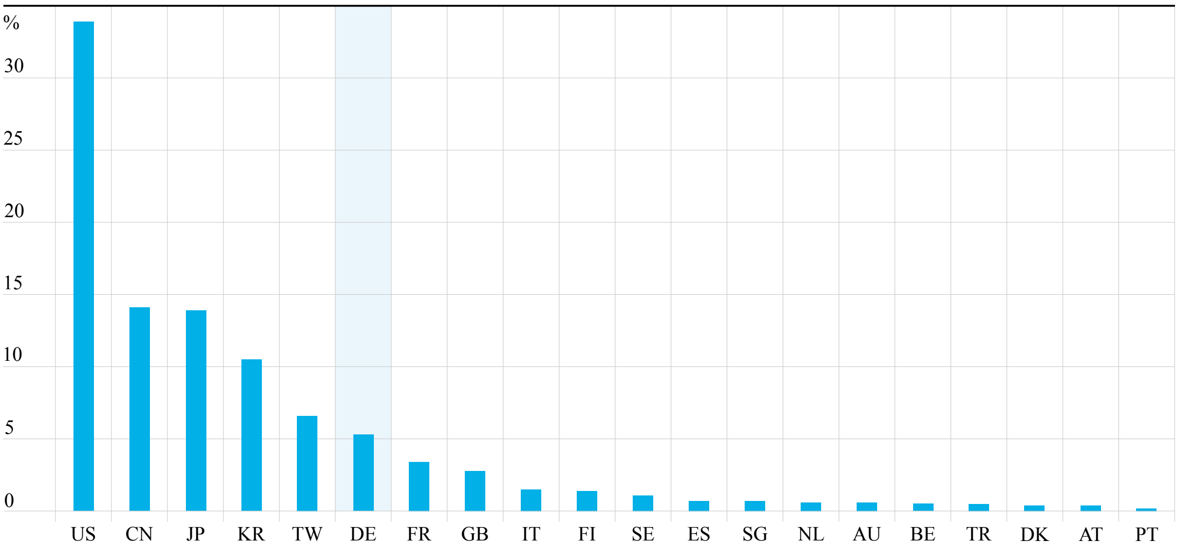

Source: Gehrke et al. (2014), calculations and NIW estimate based on OECD (ANBERD, BERD), Eurostat, complemented by national sources.

Analysis of patent applications in the field of ICT

Patents and other forms of intellectual property are playing an increasingly important role especially in ICT markets. Successful innovations strongly depend on patent protection and on legal access opportunities (freedom to operate). In the 1990s, in the period 2002–2008 and the years 2009–2012, the global number of patent applications in the ICT sector increased annually by double-digit percentages. The high technology list[394] distinguishes between six technological fields directly related to ICT. In the period 1991–2011, the communication technologies segment displayed the most dynamic development, followed by computer technology, radio and television technologies and electronics.

Table 11 shows the change in transnational patent applications between the periods 1999–2001 and 2009–2011. In the area of computer technology, the number of transnational patent applications increased from 20,346 to 26,550 in the leading countries. Ten years ago, Germany was still ranked third in this field. However, in the course of the last decade, Germany's share decreased from 10.3 percent to 6 percent. China gained considerable ground in computer technology patent applications and is now in third place and thus in front of Germany.

The telecommunications sector developed even more dynamically, with an increase in patent applications from 33,247 to 51,964. Ten years ago, Germany held a 15 percent share in transnational patent applications and thus ranked in third place, just behind Japan and at a considerable distance behind the United States – the undisputed leader in this field. Over the last decade, however, China managed to advance in the ranking, moving from former ninth place to the top of the list, even overtaking the United States. With a share of 7.3 percent, Germany now occupies the fifth position behind Japan and Korea.[395]

A study conducted in the context of the High-Tech Strategy (HTS) identified those fields of ICT that are highly relevant for the Federal Government's requirement areas as defined by the HTS.[396] The respective study shows that Germany is poorly positioned with regard to the majority of ICT fields, and that Germany displays an extremely unfavourable specialisation profile. This applies especially to displays, static memories, software, computers, and telecommunications.

Distribution of transnational patent applications in the field of computer and telecommunication in various countries

TAB 11

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	Transnational patent applications in the years 1999–2001			Transnational patent applications in the years 2009–2011		
		Number	Share in %		Number	Share in %
Computer						
	USA	9,202	45.2	USA	13,948	52.5
	Japan	5,419	26.6	Japan	5,021	18.9
	Germany	2,105	10.3	China	2,216	8.3
	France	1,176	5.8	Germany	1,586	6.0
	Great Britain	1,147	5.6	Korea	1,299	4.9
	Korea	628	3.1	France	1,132	4.3
	Sweden	285	1.4	Great Britain	824	3.1
	Switzerland	254	1.2	Sweden	311	1.2
	China	130	0.6	Switzerland	213	0.8
	Total	**20,346**	**100.0**	**Total**	**26,550**	**100.0**
Telecommunications						
	USA	14,715	44.3	China	15,791	30.4
	Japan	5,670	17.1	USA	11,947	23.0
	Germany	4,974	15.0	Japan	8,026	15.4
	France	2,284	6.9	Korea	5,262	10.1
	Great Britain	2,251	6.8	Germany	3,790	7.3
	Sweden	1,633	4.9	France	2,718	5.2
	Korea	1,052	3.2	Sweden	2,185	4.2
	Switzerland	390	1.2	Great Britain	1,967	3.8
	China	278	0.8	Switzerland	278	0.5
	Total	**33,247**	**100.0**	**Total**	**51,964**	**100.0**

Source: own depiction based on Gehrke et al. (2014).

As long as the relevant intermediate products can be purchased on the world market at reasonable prices, this does not pose a problem as such. However, it can become a problem whenever strategic dependencies arise. There are only few fields of ICT in which Germany continues to be strong today. These include e.g. power electronics, machine control systems and radio navigation.[397]

Technology spillovers between producers and users of ICT

The performance of the German innovation system cannot be ascertained through an isolated analysis of the ICT industry alone. One of the crucial factors here is the production of knowledge and the adoption and development of ICT in user industries. More than in other countries, ICT-related R&D and corresponding patenting activities in Germany are concentrated on specific user industries. Thus, in 2010, 63 percent of ICT-related patent applications were attributable to sectors outside the ICT industry. Especially the automotive and supplier industries, mechanical engineering and the pharmaceutical industry increasingly patented inventions in the field of ICT. The relative importance of ICT patents has grown significantly in most user industries. In the period 2000–2010, the share of ICT patents in all patent applications rose from 8.8 to 10.1 percent in the automotive industry, from 3.3 to 6.8 percent in mechanical engineering, from 3.7 to 5.3 percent in the pharmaceutical industry and from 1.2 to 2.3 percent in the chemical industry.

Conversely, the strong links between the ICT industry and user industries are also demonstrated by the fact that ICT companies themselves increasingly file patents in the fields of mechanical engineering, chemistry and medical technology. In terms of their R&D activities, ICT companies increasingly accommodate for the needs of their industrial clients and acquire specialised skills in the clients' fields of expertise.[398]

The importance of standardisation and standard-setting consortia

System standards and interoperability agreements play an increasingly important role in ICT and the application thereof. Early participation in important standardisation committees and an active influence on such committees are crucial competitive factors in the ICT sector. More and more ICT standards are protected by patents, and these are of central importance to the enforcement of the relevant standards and the business success of the companies involved. What is more, innovations are often dependent on a large number of patents being held by different companies. The parties involved need to have access to all standard-essential patents in order to offer products that are compatible with the respective standards in all the relevant markets.

A recent study by the European Commission reveals that more than 1,500 ICT standards are protected by essential patents.[399] Typical examples here are patents on important standards such as MP3, UMTS or LTE. In recent years, patent disputes relating to standard-essential patents have become more frequent.

In the 1990s, and also at the beginning of the 21st century, German companies took an active part in the development and standardisation of essential patents. German research institutions and companies (among them Siemens AG, Robert Bosch GmbH, and T-Mobile Deutschland) played an important role in introducing telecommunications standards such as GSM and UMTS. As a result, Germany was regarded as an important technology development centre in

BOX 13

Patent litigation on standard-essential patents

Bei standard-essenziellen Patenten (standard essen Standard essential patents (SEPs) are patents protecting a technology that is essential for complying with a given industry standard. In principle, this makes it technically impossible to market a standards-compliant product without making use of the technology protected through the corresponding SEP.[400]

Many companies try to use their standard-essential patents to the detriment of their market competitors. In 2012, Google, for instance, used the standard-essential patent portfolio acquired through the acquisition of Motorola against Apple and even obtained temporary sales bans. A similar strategy was employed by the Chinese company Huawei against its domestic competitor ZTE.

Meanwhile, both patent litigation cases have been suspended before the regional courts of Mannheim and Düsseldorf, respectively. Today, almost every company in the mobile phone industry is involved in patent disputes – both as plaintiff and as defendant. The conditions under which holders of standard-essential patents may enforce an injunction against an infringing party are currently being examined with reference to European competition law.[401] Furthermore, academic institutions and competition authorities are presently engaged in a lively debate on the future viability of the FRAND licencing model.[402]

Germany has become the central location for patent disputes, which is partially owing to the fact that disputes can be fought out relatively quickly and inexpensively in Germany.[403] The Expert Commission notes with concern that the number of disputes in the field of SEPs has increased considerably over recent years.

Beyond this, it can also be observed that an ever increasing number of "patent trolls" is attempting to legally enforce patents – sometimes of questionable quality – with the aim of giving voice to their extensive licence claims. In this context it should be ensured that the new European patent system does not provide for strategic opportunities to expose supposed infringers to high cost pressure as a means of enforcing licence claims.[404]

this area up until 2004. Also thanks to these efforts, Europe was one of the main locations for the standardisation of communication technology.

However, the proportion of standard-essential patents filed by German companies has decreased significantly since 2004. Standardisation markets and standardisation centres experienced a shift towards Asia. In contrast to earlier years, European companies no longer exerted their influence on essential standards relating to the fourth generation of mobile communications. Instead, new market participants from Asia (e.g. Samsung, Huawei, as well as the Asian network providers) are increasingly playing a key role in the process of standard-setting, while at the same time investing heavily in R&D and new product generations.[405] In the course of these developments, stakeholders from Germany have lost their relevance as holders of standard-essential patents in recent years. Furthermore, they also significantly reduced their patent-related R&D activities or moved their R&D sites to locations abroad.

In addition to official standards organisations such as ISO, ETSI and ITU, standard consortia have also become relevant players in standard setting by defining important system standards – especially in the area of internet and software. Currently there are more than 450 of such ICT-related standard consortia worldwide.[406] A study on participation in standard consortia in the ICT sector shows that German companies were very active ten to 15 years ago. In recent years, however, the influence and presence of German companies has declined significantly. Especially with regard to new, promising standards such as the HTML 5 and the cloud standard, there is a danger that Germany will be excluded at these important junctures. Cloud computing, an area that is becoming ever more topical, is largely dominated by leading stakeholders and standard-setting consortia from the United States.

The Federal Government's R&D funding in the field of ICT

Under its ICT 2020 Programme, the Federal Government has been providing targeted funding to information and communication technologies since 2007.[407] The communication sector plays a central role within the Federal Government's High-Tech Strategy. Each year, the Federal Government hosts a top-level status conference on communication during its annual IT summit. While previous public support programmes focussed on promoting ICT as a key technology on the supply side, today's support programmes are designed more along the lines of key fields of ICT applications and key ICT systems. As a consequence, research funding is now largely focussed on application areas and industries in which Germany has proven strengths, and these strengths can even be further enhanced through the use of ICT. ICT applications are supported especially in the automotive and mobility industries, mechanical engineering and automation, healthcare and medical engineering, logistics and services, as well as energy and the environment.[408]

Given the complexity of these fields, it was necessary to develop new types of strategic funding tools. Previously, the Federal Government had largely relied on three types of ICT funding tools: lead innovations, technology alliances and service platforms. The promotion of lead innovations included the creation of innovation alliances on central aspects of ICT application, among them e.g. the Automotive Electronics Initiative, the Networked Intelligent Objects in Logistics Initiative, the Safe Mobility Through Communication Technologies Initiative, as well as ICT in the field of healthcare.[409]

In addition, vertical collaborative projects involving users, manufacturers and research institutes have been established within the framework of technology networks. In parallel, horizontal organisational alliances were funded, provided that these involved the collaboration of several companies in joint ICT research domains. Examples include projects such as standards for communication of the future, virtual technologies and real products, digital product memory, as well as ambient intelligence for autonomous networked systems.[410] The instrument of service platforms was characterised by a stronger focus on services and business models. Here, projects included topics such as ICT for services and the provision of services, as well as flexible modules for communication services.

Overall, the Federal Government invested EUR 3.2 billion in ICT within the period 2007 to 2011. Of this amount, EUR 1.74 billion was allocated to the institutional funding of science organisations, and

EUR 1.48 billion was allocated to ICT project funding. In contrast to other countries, the lion's share of funds was directed towards public research organisations.[411] Since 2012, R&D funding in the field of ICT has been continuously expanded even further. To assess the effectiveness of funding, it would be necessary to conduct an evaluation of strategic funding measures in order to find out which of the above support projects has succeeded in strengthening Germany's international competitiveness. While the topics supported stand out for their diversity and complexity, they are faced with a strong consolidation of R&D and value added in the German ICT industry.

The EU's R&D funding in the field of ICT

On the side of the EU, the promotion of ICT has played a prominent role across various phases of the Research Framework Programmes. ICT has been recognised as an important general purpose technology and as a means of overcoming the productivity gap between the United States and Europe. The European Union's ICT support measures are based on three objectives: fundamental and application-oriented research into ICT, application of ICT to increase productivity and competitiveness in industry, and creating solutions to major societal challenges (e.g. in the fields of healthcare, energy, mobility) through the development and use of ICT.

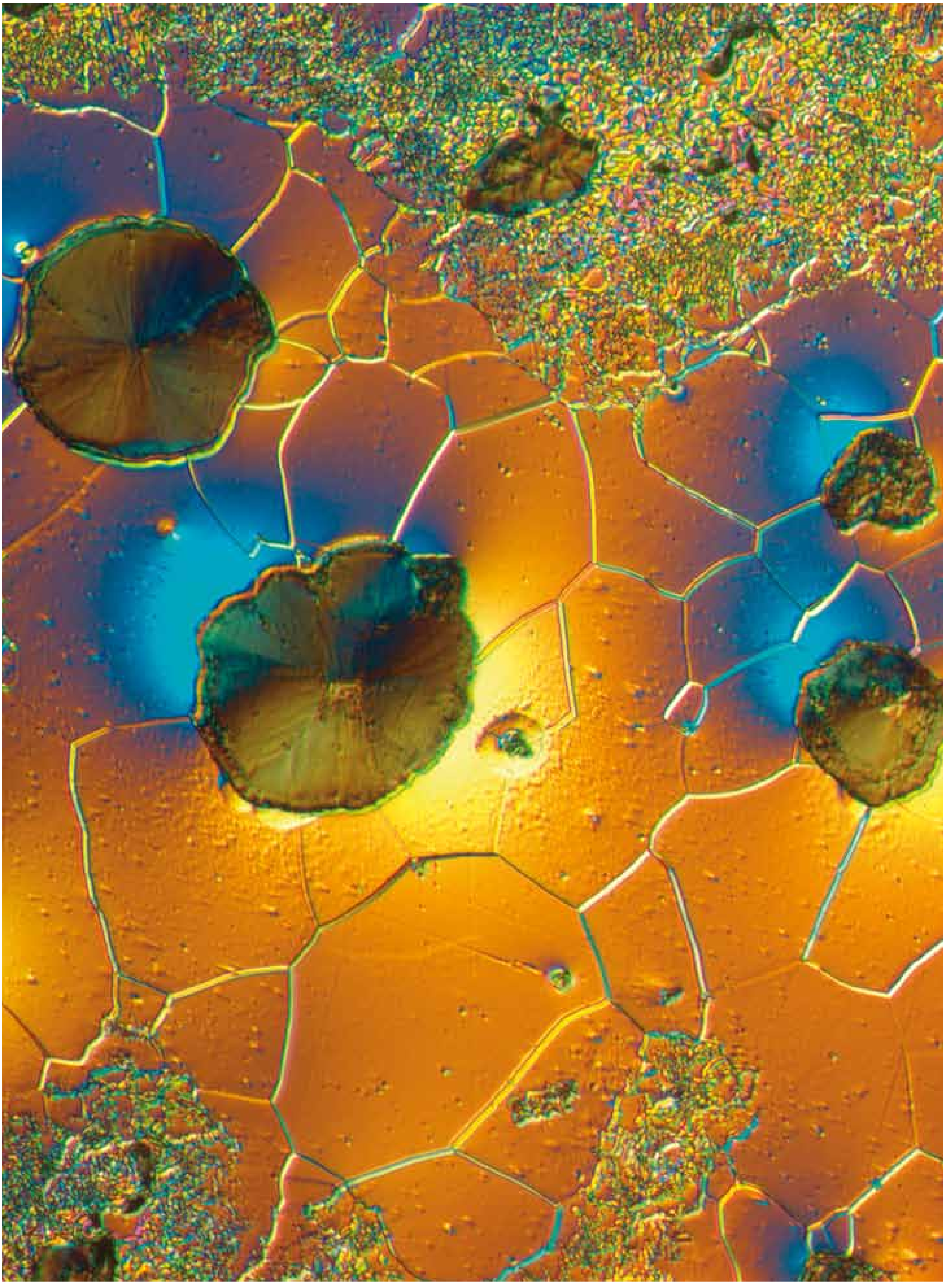
With a volume of EUR 9 billion, ICT support measurers constituted the largest budget item within the 7th Framework Programme. In the period 2007 to 2013 a total of EUR 1.5 billion was allocated to project participants in Germany, which equals 21 percent of the EU's ICT funding volume. German beneficiaries held a coordinating role in 20 percent of projects funded. Public research in Germany received 63 percent of EU funds, with 34.2 percent of this going to tertiary education institutions and 28.4 percent to non-university research organisations, while Germany's private sector was allocated 36 percent of EU funds.[412]

The follow-up programme, Horizon 2020, has a total budget of EUR 80 billion for the period 2014 to 2020. While the exact funding volume for ICT has not been published yet, it can be assumed that it will constitute a large part of the overall budget. Funding measures are strategically bundled within the Digital Agenda 2020. Furthermore, ICT plays a key role within the EU's Smart Specialisation (RIS3) strategy that aims to redesign the allocation of public funds and regional innovation initiatives.

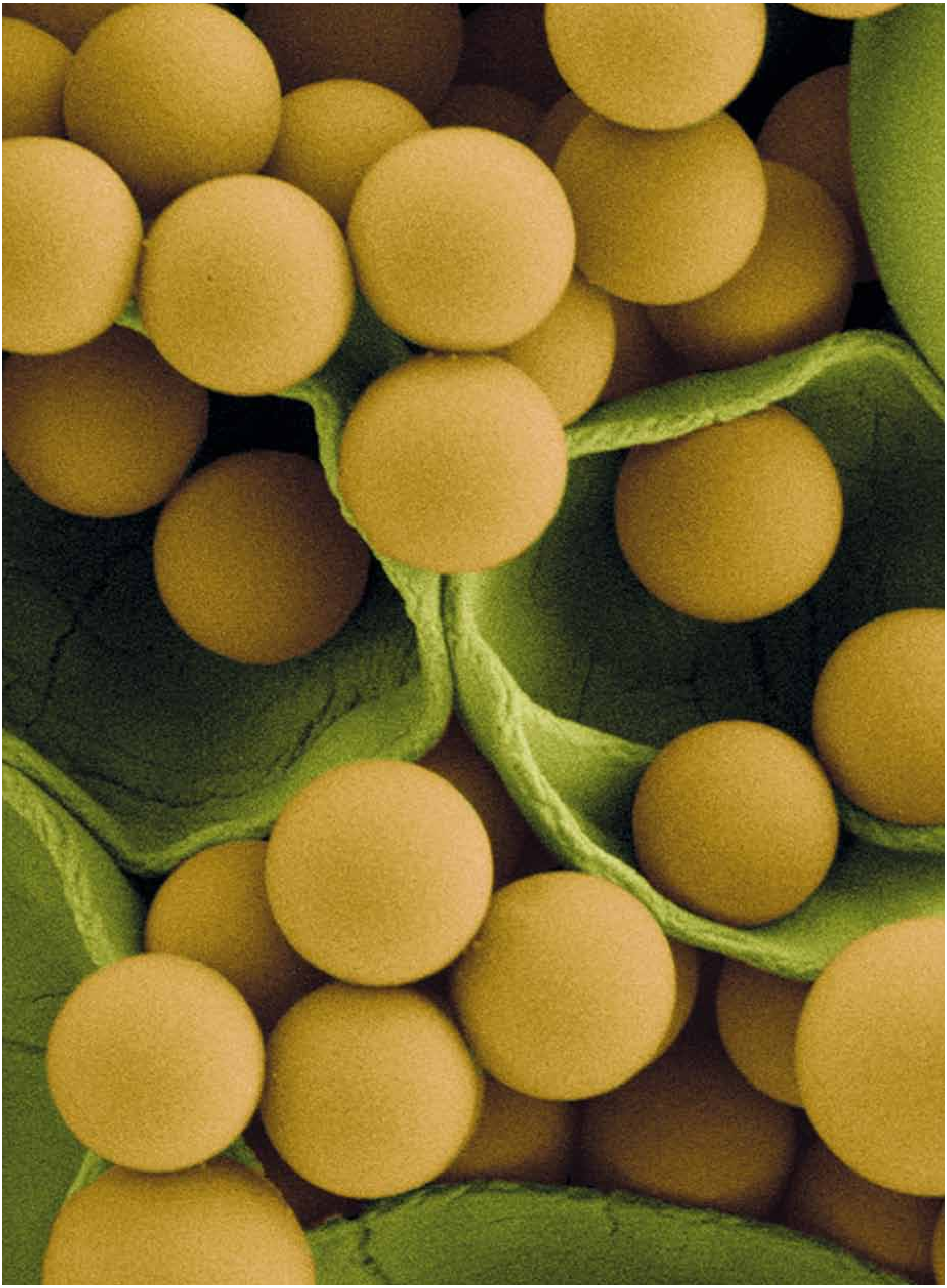
The following action areas have been specified within the Digital Agenda: creating a single market for the digital economy, enhancing interoperability and standards in the area of ICT, improving data security, facilitating high-speed internet access, enhancing digital literacy and inclusion, as well as applying ICT to address major societal challenges. Detailed objectives and concrete performance indicators have been defined for each of these action areas. The Smart Specialisation strategy focusses to a much greater extent on developing unique skills to be distributed across EU regions. The European regions are encouraged to make greater use of the potential of ICT applications and to identify specialisation advantages in specific niches in the adaptation of this technology. The development and implementation of an ICT-specific Smart Specialisation strategy is a particular challenge for Europe. The EU aims to secure value creation and employment in Europe through the development of unique ICT applications and regional competence clusters. However, the absence of strong industrial partners entails the risk that many regional solutions will merely represent reproductions of existing products and services. The Expert Commission is doubtful as to whether these initiatives will be able to substantially strengthen Europe's ICT industry.

Recommendations

High priority should be attached to the future development of ICT and its broad utilisation as a general purpose technology for business and social life. The Expert Commission welcomes the fact that the Federal Government attaches great importance to ICT, which has also been documented in the coalition agreement. The Digital Agenda for Germany as proposed in the coalition agreement defines guidelines for the development of the digital economy and infrastructure for enhanced digital education and research as well as the broad utilisation of ICT in the workplace and in social life.[413] While these objectives are a step in the right direction, the coalition agreement does not specify in detail how objectives are to be achieved and what constraints are to be



Reflected-light microscope with polarised light and differential interference contrast.



Coloured scanning electron microscope image.

overcome. With regard to the future course of this process, the Expert Commission would like to suggest the following recommendations.

The Digital Agenda for the period 2014–2017 is to be elaborated in consensus between businesses, social partners, civil society and academia.[414] When adopting and implementing the Digital Agenda for Germany, the following points should be taken into account. The use of resources and the attention of the public sector should be focussed on specific ICT applications that are highly relevant for the future economic and social development in Germany. These applications should also be closely linked with the Federal Government's requirement areas as specified in the HTS and the funding priorities within the EU's Horizon 2020 framework programme. With regard to defining the priority fields of ICT application, the Expert Commission endorses the recommendations made at the previous IT summits, as well as those made in a study on the application potentials of telecommunications.[415] Based on this, the most important topics include:

– Future production systems, digitalisation, and Industry 4.0;
– future mobility, automotive and new transport systems;
– innovative medical systems, healthcare and e-health;
– future energy system, smart grid and energy system optimisation;
– utilisation of ICT to optimise trade, distribution and logistics.

The structure of value chains should be analysed for each of these fields of application, and the most critical development stages and skills areas should be highlighted clearly. The smart utilisation and the development of new ICT services and business models should be at the core of Germany's future development in ICT. Support measures should strategically focus on those components and IT products that are particularly critical and require geographic proximity – and are thus essential for securing these fields of application.

Innovations in the field of ICT are being globally advanced by start-ups and international growth strategies of young ICT enterprises. With regard to entrepreneurship in ICT, Germany is less dynamic than many of its analogue countries, and only few German ICT businesses embark on ambitious international expansion strategies. Too many potential entrepreneurs relocate to other countries, and ICT companies with a high growth potential are often taken over by foreign companies at an early stage. Suitable instruments for the support of new enterprises and growth financing should be employed to ensure that strong German companies continue to be represented in the international ICT growth markets.

Business success in the field of ICT largely depends on system standards and standard essential patents. If Germany is to position itself in important fields of technology, it will have to actively participate in major standard setting consortia and standardisation organisations at an early stage. The coalition agreement includes only vague statements on a comprehensive standardisation strategy. The Expert Commission therefore strongly advocates strategic standard monitoring and an active and coordinated participation of German companies and research institutions in the most important international standardisation processes.

The digitalisation of production systems and value chains will bring about fundamental changes in the years to come. To address these developments, the Federal Government has launched its Project of the Future: Industry 4.0, a project that has also been highlighted in the coalition agreement. Due to its strong focus on the links between ICT, internet and production, Industry 4.0 can be considered a very important initiative. In the context of the Industry 4.0 project it should be ensured that system solutions have an international design and that Germany takes a decisive role in shaping international ICT standards for production and automation technologies. Governments in the United States, Japan and China have launched similar initiatives, albeit with a focus on cyber-physical systems. Parallel or concurrent developments should be avoided as early as possible.

Many experts consider cloud computing and new ICT architectures as the next revolution in ICT.[416] The decisive factor here is to identify both the leaders and the beneficiaries of cloud solutions. On the user's side, SMEs are potential beneficiaries as cloud technologies enable them to use IT technologies that were previously available to large companies only. Pilot applications could be used to demonstrate practical suitability, as well as new applications and data security to users in SMEs in particular. On the supply side, measures should be taken to ensure that cloud computing infrastructures can be developed in Germany or at least at a European level. The market is currently dominated by large ICT corporations and IT providers from the United States. These companies exploit their advantages over European providers who are disadvantaged due to different national safety standards, data protection regulations and processes. Priority should be attached to creating a uniform legal framework for cloud computing. The current draft of the EU Regulation on data protection still includes a number of issues that limit the flexibility of European companies. The Federal Government should endeavour to ensure that a European standard for cloud security is created.[417]

To achieve a rapid diffusion of the latest ICT, a coordinated policy is needed between the Federal Government, the *Länder* governments and the communities in the area of broadband infrastructure. New applications in the fields of education, healthcare and e-government will only be able to unfold positive effects if they can be provided via broadband networks. When compared with other countries, Germany has yet to catch up in this regard. Germany is still characterised by high disparities across federal states and a pronounced gap between rural and urban regions.[418] The Federal Government intends to launch a programme for expanding high-speed internet accessibility by 2018. The Expert Commission welcomes this initiative. However, additional steps should be optimised along the lines of economic principles; full provision at any cost cannot be the goal here.[419]

In the area of e-government, Germany is currently in midfield when compared internationally. E-government makes an important contribution to the public accessibility and efficiency of public administration. E-procurement, i.e. the electronic tendering and awarding of procurement contracts, can play a central role in ensuring efficiency in the public procurement system. The Federal Government should attach the highest priority to promoting the use of ICT in government services. Efforts in this area would also generate positive effects on the demand side of the ICT industry.

The ICT support strategies of the EU and the Federal Government continue to show a lack of systematic evaluations that would ensure an efficient and effective allocation of funds. In this regard, it should also be assessed whether research funds allocated succeed in sustainably improving the competitiveness of the ICT industry in Germany and the EU.

Finally, R&D tax credits would ensure that especially research-intensive SMEs, which play an important role in ICT, can benefit from funding measures. The Expert Commission therefore reiterates its call for an immediate introduction of R&D tax credits.

B 4 THE ROLE OF WOMEN IN THE INNOVATION PROCESS

B 4–1 MAKING USE OF GERMANY'S INNOVATION POTENTIAL THROUGH GREATER INVOLVEMENT OF WOMEN IN THE INNOVATION SYSTEM

Women are underrepresented in the German innovation system. Compared to men, women are less often enrolled in STEM (Science, Technology, Engineering, and Mathematics) degrees and are also less active in the field of research and development (R&D). This imbalance is particularly pronounced in leadership positions in industry and research. And in Germany, these gender specific differences are especially striking.[420]

Considerable innovation potential is thus squandered; innovation potential that Germany in particular depends on as an innovation-based country:

– Germany underexploits the potential of well-educated women. Especially in light of the foreseeable shortages of skilled labour, Germany can no longer afford this.
– The potential that emerges from the diversity of team members is not exploited. Groups that are heterogeneous in their demographic or cultural composition tend to display a more creative approach to problem solving than homogeneous groups.[421]

In its Annual Report 2013, the Expert Commission already pointed out that demographic change is going to systematically alter the size and age structure of Germany's labour force in the long run. In the future, the number of qualified workers will decrease, in STEM professions in particular. This will lead to a bottleneck in the innovative capacity and competitiveness of German companies and Germany as a business location. Therefore, it will be increasingly important to make better use of the skills and innovative potential of women; a potential that continues to be underexploited to date. Against this background, the educational expansion of the last decades can be regarded as highly successful: today, more women than men obtain a university degree. Yet, female students systematically opt for different fields of study than male students. Female students only rarely choose a STEM subject; and especially engineering courses are frequently being neglected. What is more, the increasing success of women in the education system does not result in similar subsequent success in the labour market. Instead, Germany loses the potential of the ever-growing number of highly qualified women in the transition to the labour market and in the subsequent career progression.[422]

Integrating highly qualified women into the innovation process will not only lead to quantitative effects; an increased diversity among staff will also result in qualitative effects. The heterogeneity of a group – in this case a company's or an institution's staff – in terms of gender, ethnic background, age, religion, origin, etc., and the associated different life experience and know-how of the individual group members result in multiple perspectives and ideas, which, in turn, may contribute to new problem-solving strategies. If a given issue is viewed from different perspectives, this means that traditional views can be challenged and complemented by aspects that might have been previously disregarded. The interplay of different types of know-how and qualifications, experience and skill sets stimulates creativity and innovation in both processes and products. Moreover, the heterogeneity of a group facilitates the understanding of different client groups and their product-related needs and allows for the adjustment of business strategies according to these needs.

Empirical studies suggest that a more balanced ratio between men and women has a positive effect on several corporate performance figures. Companies with mixed teams and women in executive roles perform better in terms of sales, revenue, clients and profit.[423] Particularly, studies suggest that women are valuable in executive roles in those cases where the corporate strategy is innovation-based.[424] Women have a positive effect on innovation activities and the success of newly established enterprises.[425]

In addition, a greater participation of women in the innovation process also results in new forms of innovations. An expert group established by the European Commission has developed the term "gendered innovations" to describe this phenomenon. The concept of gendered innovations goes beyond the participation of women in innovation processes or in teams. "Gendered innovations" means that aspects of sex and gender are incorporated into basic and applied research to ensure scientific quality and excellence and to develop more targeted solutions. In this context, sex refers to the biological distinction between men and women, whereas gender refers to the socio-cultural role of women and men in society. While e.g. the development of efficient medications can be improved by considering sex, socio-cultural aspects play an important role e.g. for optimising public transport systems for different user groups, or for developing customer-oriented software solutions.[426]

B 4–2 ACADEMIC AND LABOUR MARKET SUCCESS OF WOMEN IN THE SCIENCE SYSTEM

Selection of field of study and academic success in STEM subjects

In Germany, an average of about 25 percent of female first-year students opt for STEM subjects, as opposed to 50 percent of male first-year students. Within the STEM subjects group, the share of female students varies greatly: in 2012, the share of women among first year students in biology and mathematics courses was 63.4 and 50.5 percent, respectively. Only 23.1 percent of female first-year students took up a course in engineering, and a mere 12.6 percent opted for a course in electrical engineering.[427]

With regard to the share of students graduating from engineering degree courses, Germany is lagging considerably behind when compared with other OECD countries. In 2011, 22 percent of engineering graduates in Germany were female, while frontrunners such as Iceland and Greece recorded a 40 percent share. Italy and Spain, with 33 and 32 percent respectively, also display a relatively high share of female engineering graduates, and the same goes for the Scandinavian countries of Denmark and Sweden with 32 and 30 percent, respectively.[428]

Higher share of women in engineering in Germany's new federal states

A comparison of the share of women in technical degree courses in Germany's new and old federal states shows that cultural differences from the pre-reunification era are still having an effect today. It is still the case that in the new federal states more women graduate from engineering degree courses than in the old federal states.

The GDR government systematically directed university entrants into technical degree courses as a means of promoting technical research and innovation. Based on measures such as the "mobilisation of women for engineering education" new target groups were developed from the mid-1950s. In 1986, the share of women among students in technical degree courses amounted to approximately 30 percent.[429]

In the mid-1950s, the Federal Republic of Germany also began to focus more on the small number of engineering students. To address this issue, attempts were made to recruit new target groups for engineering degree courses, among them women and pupils with non-academic backgrounds. In spite of these efforts, by 1989, the share of female students and graduates in engineering had only reached 12.3 percent and 10.6 percent, respectively.[430]

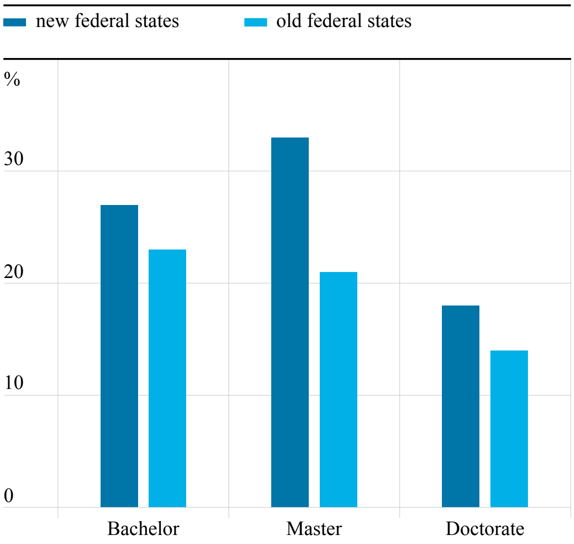
After the reunification of Germany a systematic decrease in the share of female engineers in the new federal states was initially observed, i.e. the levels were gradually aligned with those of the old federal states. Yet, when comparing the percentage distribution of graduates (bachelor, master, doctorate), it can be observed that even today, differences in German-German history have an impact on the participation of women in engineering sciences. In a 2010 comparison of the new and old federal states, the new federal states recorded significantly higher shares of women across all three degree levels (cf. Figure 31).[431]

Underrepresentation of women in STEM subjects increases in career progression

The problem of underrepresentation is systematically exacerbated in the further employment and career progression. Figure 32 shows the academic career paths of men and women across different fields of the STEM subjects group. It can be clearly seen that at the top of the career ladder the share of men far exceeds that of women. Remarkably, this is the case even in the fields of medicine and biology – fields in which the number of female first-year students significantly exceeds that of male students.

FIG 31 **Share of female graduates in engineering sciences in 2010** (figures in percent)

DATA DOWNLOAD



Source: Ihsen et al. 2014.

While the gender ratio is at least balanced during the doctoral phase, a dramatic shift to the detriment of women can be observed at the professorial level. The problem of utilising the potential of women takes quite a different shape in the field of life sciences than in the engineering sciences. While the latter fail to attract sufficient numbers of female students, life sciences are losing a large share of female graduates in the course of their career. While this gap has closed somewhat in all subject areas in the last decade, differences continue to be pronounced – especially at the highest career levels. This widening gap can also be observed in similar forms in other countries.

B 4–3 WOMEN IN LEADERSHIP POSITIONS IN ACADEMIA

In Germany, the share of female professors was at 19.2 percent in 2010 (6.5 percent in 1992) across all subject groups. The higher the remuneration group, the lower the share of women. In 2010, the share of women in W1 professorship positions (junior professorships) was at 37.8 percent, the C2 positions (permanent and temporary) at 21.1 percent, the C3/W2 positions at 20.1 percent and C4/W3 positions at a mere 14.6 percent.[432]

In recent years, however, the representation of women in appointment procedures has undergone a positive development. Between 1997 and 2011 the share of female applicants for professorships increased from 12.9 to 23.7 percent. Appointments of female professors increased from 16.9 percent to 26.8 percent, and the number of nominated female professors went up from 15.7 to 26.7 percent.[433] Furthermore, the share of women in leadership positions in universities has more than doubled, with an increase of 9.8 percent to 20.7 percent between 1996 and 2011.[434]

Table 12 shows the share of women in scientific leadership positions in international comparison. In Germany, the share of women at the highest academic level (the equivalent of C4/W3 professorships in Germany) was at 14.6 percent in 2010. With a share of 9.8 percent, female representation is significantly lower in natural sciences, and also in engineering sciences (5.9 percent). Although in these subject groups the comparison countries also recorded a lower share when compared with the average percentage for all subjects, female representation in Germany is still very low by international standards, and even features at the bottom of the list in the engineering sciences.

Female representation disappointing even after the launch of the DFG cascade model

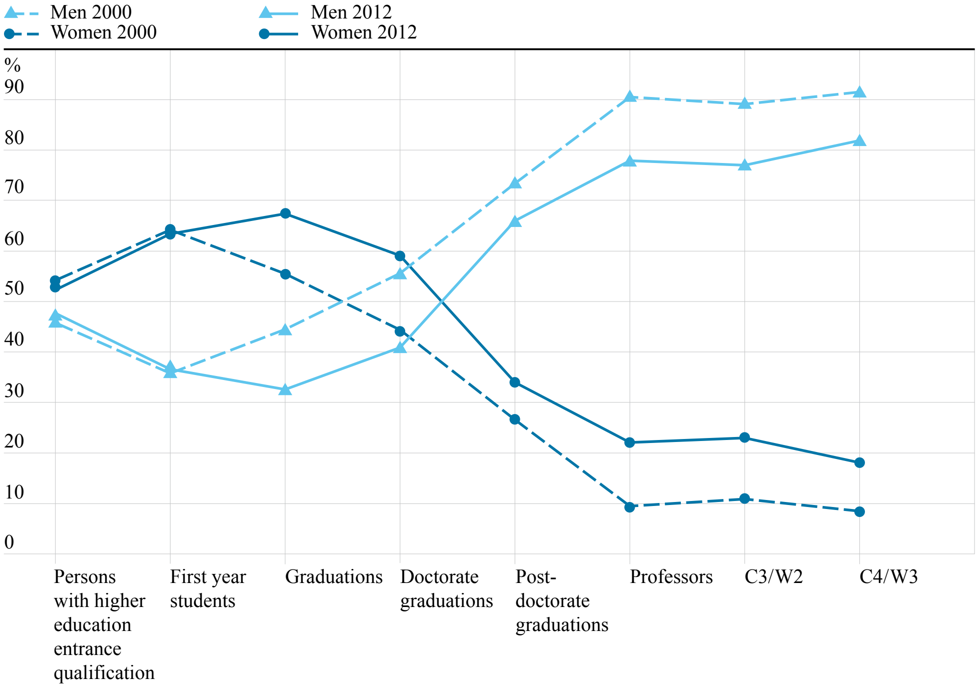
In 2008, the German Research Foundation (DFG) adopted research-oriented standards on gender equality. The aim has been to significantly increase the share of women at all stages of the scientific career. The guiding principle of this approach is the “cascade model”. According to this model, the share of female scientists of a certain qualification level has to be raised to the share of female scientists in the qualification level directly below.[435] Table 13 shows the initial values, the target values, and the current situation in terms of the representation of women in professorships at the elite universities.

The development of the share of women at the various career stages has fallen short of the DFG’s expectations. On 3 July 2013, the DFG’s general assembly therefore adopted a package of measures, placing even stronger emphasis on the numerical development in the share of female scientists. The implementation of the gender equality standards

FIG 32 **Share of women at different career stages in academia 2000 to 2012** (figures in percent)

Biology

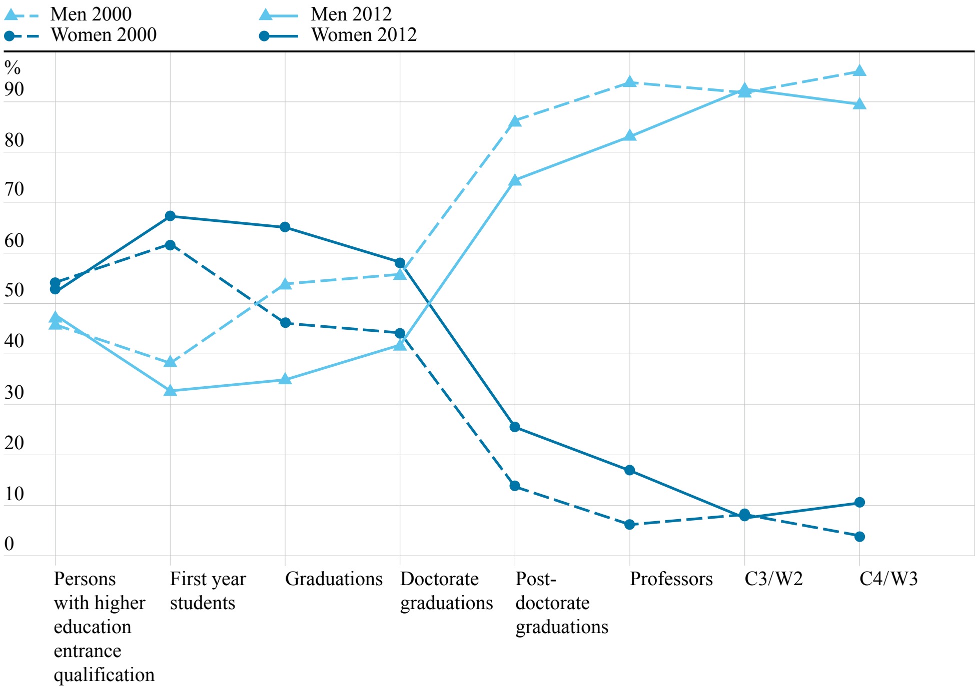
DATA DOWNLOAD



Source: Statistisches Bundesamt.

Human medicine, health sciences

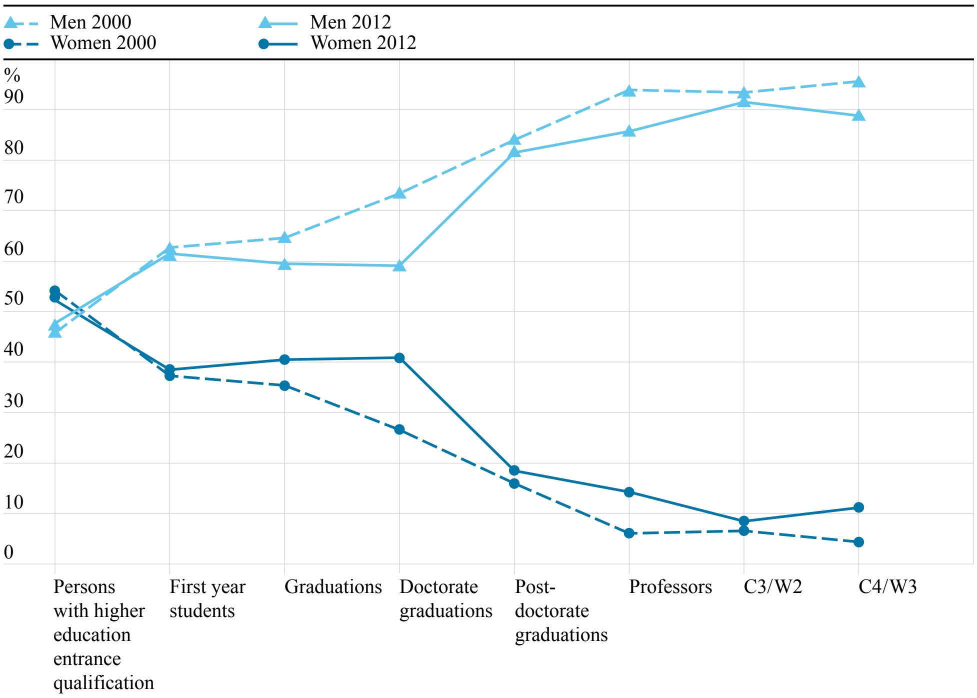
DATA DOWNLOAD



Source: Statistisches Bundesamt.

Mathematics and natural sciences

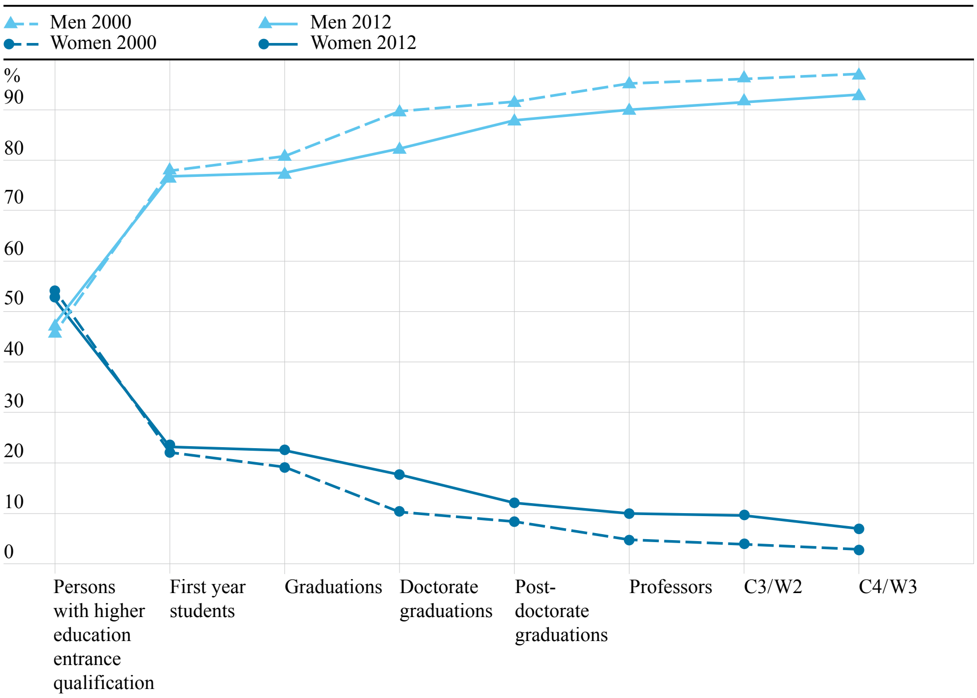
DATA DOWNLOAD



Source: Statistisches Bundesamt.

Engineering sciences

DATA DOWNLOAD



Source: Statistisches Bundesamt.

TAB 12 **Share of women in academic leadership positions in 2010**
(figures in percent)

DATA DOWNLOAD

	AT	CH	DE	FI	FR	GB	IT	NL	SE	US
Share of women in…										
professorship roles (2002)	17.4 (9.5)	25.9 (11.0)	14.6 (8.0)	24.2 (19.9)	18.7 (17.3)	17.5 (15.1)	20.1 (15.6)	13.1 (8.2)	20.0 (14.0)	21.9 (–)
professorship roles in natural sciences	7.6	11.8	9.8	11.8	–	9.0	19.8	8.5	14.3	21.2
professorship roles in engineering sciences	7.7	15.2	5.9	7.4	–	7.0	9.5	6.8	10.1	7.7
university leadership positions	16.2	15.8	11.7	25.0	6.5	–	23.4	13.6	26.9	29.0
scientific committees	31	21	21	45	27	31	17	29	49	–

Source: European Commission 2013b; NSF 2013.

TAB 13 **Target quotas and current share of women at the elite universities**
(figures in percent)

DATA DOWNLOAD

	C4/W3 professorships		
University	**Current situation 2008/2009**	**Set target 2013** [1]	**Situation 2012**
RWTH Aachen University	3	–	9
Freie Universität Berlin	20	22	25
Humboldt-Universität zu Berlin[3]	19.3	15.1	18.3
University of Bremen[3]	19	21–25	21
Dresden University of Technology[3]	5.6	10	5.9
University of Freiburg[2]	10	25	17
University of Göttingen[2]	13	17	17
Heidelberg University	11.5	–	14.8
Karlsruhe Institute of Technology[2]	10[4]	13[4]	10[4]
University of Cologne[3]	15.2	–	17.4
University of Konstanz	17	30	23
Ludwig Maximilian University of Munich	9.8	16	14.8
Munich University of Technology	8	15	10
University of Tübingen[3]	12[4]	17[4]	17[4]

[1] The targets for 2013 were first set in 2009, providing for possible adjustment in 2011.
[2] Funded for Future Concepts only in the first round of the Excellence Initiative 2007–2012.
[3] Funded for Future Concepts only in the second round of the Excellence Initiative from 2012.
[4] Total number pf C3/W2 and C4/W3 professorships.
Source: Final reports on DFG's Research-Oriented Standards on Gender Equality

TAB 14

DATA DOWNLOAD

Target quotas and current share of women in non-university research institutions
(figures in percent)

Fraunhofer-Gesellschaft		Actual quota 2012	Target quota 2017
Stage 1	Leadership level 1 (directing staff of Institute)	5	11
Stage 2	Leadership level 2 (heads of departments and teams)	14	16
Stage 3	Scientists (below leadership level 2)	23	26

Helmholtz-Gemeinschaft		Actual quota 2012	Target quota 2018
Stage 1	W3 professorships	11	14
Stage 2	W2 professorships	15	20
Stage 3	Heads of working groups (below W2 level)	18	22
Stage 4	Academic staff with an unlimited contract of employment (below heads of working groups; above doctoral candidates)	16	18
Stage 5	Academic staff with a limited contract of employment (below heads of working groups; above doctoral candidates)	29	34
Stage 6	Doctoral candidates	43	43

Max-Planck-Gesellschaft		Actual quota 2012	Target quota 2017
Stage 1	W3 professorships	8.7	13.7
Stage 2	W2 professorships	27.4	32.4
Stage 3	Academic staff employed as per collective agreement	28.3	33.3

Leibniz-Gemeinschaft		Actual quota 2012	Target quota 2017
Stage 1	W3 professorships	12.1	13.5
Stage 2	W2 professorships	17.9	23.1

Source: GWK 2013.

is supposed to be linked more closely with the funding process, i.e. all funding applications for research consortia are required to specify the number of female scientists to be involved on each of the qualification stages. In addition, all tertiary education institutions are required to supply quantitative information on gender equality on an annual basis.[436]

The Federal Government's Pact for Research and Innovation requested from non-university research institutions to specify flexible target quotas according to the cascade model of research-oriented standards on gender equality. In 2012, they responded to this request and declared individual target quotas for different career levels for the year 2017. These are summarised in Table 14.[437]

It is yet too early to assess whether the research organisations are taking sufficient action to achieve these goals. However, the Expert Commission feels that the objectives of the non-university research organisations – and those of the tertiary education institutions – are generally lacking ambition when measured against the cascade model. Based on that, the target shares of the different levels should be closer to the actual shares of the qualification levels below. Here, the opportunity to publicly commit to increasing the participation of women in the German science system was missed.

WOMEN IN LEADERSHIP POSITIONS IN THE PRIVATE AND PUBLIC SECTORS B 4–4

More women achieve leadership positions in the new federal states

Differences in German-German history are evident not only in engineering but also in the share of women in leadership positions. In the new federal states this share is higher than in the old federal states (cf. Figure 33). Arguably, this is due to the fact that prior to Germany's reunification, women traditionally played a more prominent role on the labour market in the new federal states, and still do so today. Even today, childcare infrastructure is further developed in the new federal states, and employment rates of mothers and the share of women in full-time employment are also higher.[438] In the new federal states, between 35 and 44 percent of mothers with a child under the age of three are economically active. In the old federal states, this ratio is only between 28 and 34 percent.[439]

In recent years, the share of women in the top management level of companies with 500 or more employees has increased considerably. These companies previously recorded the lowest share of women in executive roles. In these companies, the share of women at the top management level increased from 9 percent in 2008 to 19 percent in 2012. This increase is primarily attributable to changes that have taken place in the old federal states. Between 2008 and 2012, the share of women at the top management level increased from 8 percent to 23 percent in the old federal states and is now higher than the value of the new federal states, where the share remained unchanged with 17 percent.[440]

Voluntary commitment has shown only little effect

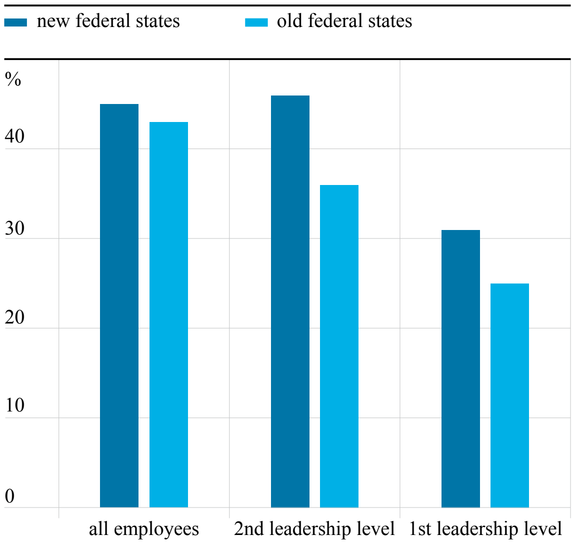
In May 2010, the Government Commission "German Corporate Governance Code"[441] amended their guidelines, including the requirement for listed companies to adequately provide for women when filling management positions and when appointing executive board and non-executive board members. According to the Code, the target of the non-executive board and the status of implementation shall be published in each company's corporate governance report.[442]

A recent study[443] examines whether the DAX companies have met the requirements laid down in the German Corporate Governance Code in their 2010 corporate reports and whether changes can be observed in comparison to the previous year. It turns out that all of the companies have indeed made qualitative statements on the topic of women in executive roles. Yet, only 21 companies have provided

FIG 33

Share of women in leadership positions in 2012
(private sector, figures in percent)

DATA DOWNLOAD



Source: own depiction based on Kohaut and Möller 2013.

concrete quantitative information on the intended share of women on their non-executive boards, and only 15 companies have specified the year by which the target is to be achieved.

In Germany, the share of women on non-executive boards of DAX, MDAX, SDAX and TecDAX companies increased from 10 percent to 17.4 percent between 2011 and 2013. With an increase from 3 percent in 2011 to 8.2 percent in 2013, the share of women in non-executive boards appointed by shareholders has considerably improved recently. Yet, when measured in absolute terms, it is still at a very low level. Traditionally, more women are appointed to non-executive boards in Germany as employee representatives. Already in 2011, their share in relation to the overall non-executive board was 7.8 percent and increased only slightly to 9.2 percent by 2013. The share of women on executive boards was at 6.1 percent in 2013. The ratio thus doubled, starting from a very low level of 3 percent in 2011.[444]

Not only in Germany, but also in other European countries, women are clearly underrepresented in the highest decision-making bodies (cf. Figure 34). On average, women only had a 14 percent share within the EU-27 in 2012. With a value of 16 percent, Germany was above average, but well behind the

FIG 34

Share of women in the highest decision-making committees of the largest listed companies in Europe in 2012 (figures in percent)

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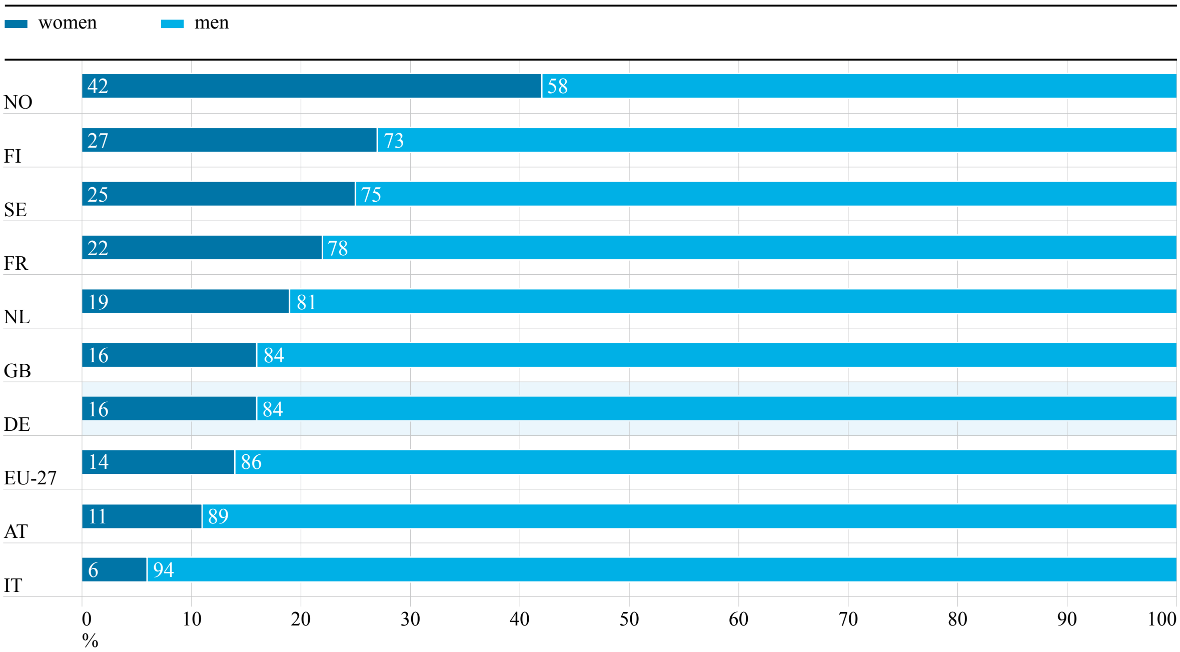


Source: own depiction based on Holst et al. 2012.

Scandinavian countries of Norway (42 percent), Finland (27 percent) and Sweden (26 percent), as well as France (22 percent) and the Netherlands (19 percent). The high share recorded in Norway is the result of a targeted policy (cf. Box 14).

Recent legislative initiatives in Germany and Europe

In the course of the coalition negotiations in Germany, the involved parties have agreed to introduce a quota for women on non-executive boards of German companies. In particular, it was agreed that from 2016 non-executive boards of fully co-determined and listed companies shall exhibit a gender quota of at least 30 percent. In the event that this quota is not achieved, the respective chairs of the under-represented sex shall remain vacant.[445]

The Expert Commission welcomes this initiative, but points to the scope of interpretation entailed in the wording.[446]

At the same time it should be noted that the share of women on executive boards is still significantly lower than on non-executive boards (6.1 percent as opposed to 17.4 percent). While the legislator can influence the representation of women on non-executive boards, this cannot be done at executive board level. Here, the companies themselves are required to take action – especially since the way to the non-executive board often leads through an executive position. Thus, to increase the number of qualified and experienced women on non-executive boards, increased representation of women on executive boards is urgently needed. In light of this, the insufficient results of the DAX companies' voluntary commitment are all the more worrying.

The issue has also gained momentum at EU level. In November 2013, the European Parliament voted for an EU Directive according to which companies listed on stock exchanges within the EU must exhibit a female share of at least 40 percent on their non-executive boards by 2020. If a company fails to achieve this quota, it is required to specify the reasons and give proof of measures by which the objectives shall be met in the future. Furthermore,

BOX 14

Norway: the effects of a mandatory quota for women on non-executive boards

In 2003 Norway enforced a law stipulating a mandatory 40 percent quota for women on non-executive boards of listed companies by July 2005 – starting from a 9 percent share in 2003. Since these requirements were not met, the government enforced another law in 2006, which then provided for a transitional period of two years and the dissolution of a company in case of failure to meet the required quota. All of the listed companies finally met the quota in April 2008. Recent studies[447] report both negative and positive effects on the respective companies' share prices following an increase in the share of women – depending on the age and experience of the respective women on the non-executive board and the resulting information gap between the non-executive board and the executive board. This means that negative price movements were largely attributable to the fact that, on average, the new female non-executive board members were younger and less experienced than their male counterparts. Another study shows that redundancies were lower in companies affected by the quota system and these companies therefore recorded lower short-term profits due to higher labour costs.[448] Information on long-term profits is not available.

The experience gained in Norway illustrates the necessity for companies to engage in developing qualified staff potential for female non-executive board members at an early stage.

penalties may be incurred in cases where companies fail to introduce suitable recruitment processes. Another suggested sanction would be to exclude noncompliant companies from public tenders. For the Directive to enter into force it has to be adopted by the Council of Ministers.[449]

Women in leadership positions in the public sector

Germany's public sector features a higher share of women in leading positions in comparison to the private sector. This applies to the top level in particular (38 percent as opposed to 26 percent). However, in interpreting this gap, it must be taken into account that the share of women of all employees is also significantly higher in the public sector (60 percent as opposed to 43 percent in the private sector). Measured by their share of employment, women at the top level are (under)represented to approximately the same extent in the private sector and the public sector.[450]

MANIFOLD REASONS FOR LOW PARTICIPATION OF WOMEN B 4–5

School, course selection and studies[451]

The course for different study choices is already set during school and preschool years. Gender-specific differences in children's relationship to science and technology cannot be observed during infancy. Also, in primary school, the performance of girls and boys in mathematics is approximately the same. Yet, already in early childhood, the interest of boys and girls in natural sciences and engineering is fostered differently. It is only with the adoption of the female gender role during puberty that girls' interest in mathematics and science decreases as this is in conflict with common female role models.

Boys' and girls' differences in assessing their own mathematical and technical skills are much larger than their actual performance differences. Girls perceive their own performance as lower than what their actual results suggest. This perception affects their educational and professional pathways, since a positive assessment of one's own technical skills is an important prerequisite for choosing an advanced course or a degree programme in a STEM subject.

In addition to schooling and the encouragement or discouragement on the part of the teachers, a person's family and social environment are considered as key factors for the decision to take up a STEM degree course. Another important factor are female role models in STEM fields of study or STEM professions.

The design of degree courses also plays an important role: female students are more likely to take up an engineering course if it is clear that the course is interdisciplinary and application-oriented.

Already the course specialisation marks an important step towards future career development. The fact that women are only rarely represented at the highest stages of the career level – i.e. as executive board members and chairs of executive boards – is partially attributable to times of absence from the labour market and decisions in favour of the family. Yet, another important factor are the areas of work women tend to choose: senior managers from the fields of HR, research and development and IT are less frequently promoted to CEO than senior managers from sales, production or finance. Women in executive roles, however, are most frequently found in HR.[452]

Difficulties in reconciling work and family life

In the male-dominated STEM professions it is particularly difficult to reconcile work and family life.[453] The professional culture is based on permanent availability and long periods of attendance.[454] Generally, leadership positions are not only characterised by full-time employment but often involve extra time. In fact, both men and women in leadership positions perceive their working days as being too long: the desired working hours are well below the actual hours worked.[455]

Furthermore, a study on Germany clearly confirms the link between childcare infrastructure and the employment of mothers. In 1996, the introduction of the legal right to a nursery school place for three-year-old children in Germany resulted in the fact that more mothers took up employment.[456] In the United States it has been demonstrated that a non-family-friendly work environment lowers the labour force participation of mothers.[457]

The effects of other measures aiming to promote the reconciliation of work and family life are less clear. A study on the relationship between family-friendly policies and the labour market participation of women in the United States suggests ambivalent effects. Although measures such as part-time work or parental leave facilitate the (re)entry of women into the labour market, they also entail the risk that women will decide against full-time or senior positions, thereby sacrificing career opportunities.[458]

The effects of part-time employment on women's labour force participation rates and career opportunities need to be considered separately. Part-time work often impedes career advancement as leadership positions are usually designed as full-time activities. Thus, Germany and Austria for instance, both of which feature a relatively high share of women in part-time jobs, record a high labour force participation of women. However, in both countries the share of women in leadership positions is low. It appears that Sweden has been more successful in solving this issue: while Sweden displays a high part-time rate, both labour participation and the share of women in leadership positions are relatively high.[459] These differing career structures are certainly owing to the fact that a part-time job in Germany and Austria comprises a significantly lower average number of hours when compared to Sweden.[460] In Germany, part-time employment is largely understood as comprising half the number of hours than that of a full-time job – or even less. In Sweden, however, the average number of part-time working hours is one third higher. Further, it is of concern that a (gradual) upward adjustment is often difficult to achieve once working hours have been reduced to a part-time level. This makes it virtually impossible to advance on the career ladder. A more flexible approach is needed here: part-time models should allow for different numbers of hours, including near full-time employment, and provide more flexibility for both parents. This would be an important step towards improving the compatibility of career progress and family life.

In order to prevent part-time employment from representing a career obstacle, it will be important to overcome the paradigm according to which leadership positions can only be performed on a full-time basis, often incurring significant overtime.[461]

Stereotypes and lower tendency for competitive behaviour as career barriers

Informal, male-dominated networks strongly affect employees' career opportunities. Access to these networks is generally based on the feature of similarity. Decisions on promotions and recruitment are often made on the basis of similarity to prevailing stereotypes – and in the male-dominated boardroom these are male. This makes it difficult to overcome stereotypes, and prevailing structures at management level and in promotions keep perpetuating themselves.[462]

Stereotypical role models represent another obstacle to the career progress of women. While the typical man is depicted as being assertive, achievement-oriented, competitive, independent and confident, the typical woman is considered to be accommodating, empathic, dependent, socially-minded and caring. These notions affect the evaluation of the performance and potential of women, since the characteristics of the typical man are fairly consistent with the stereotype of an executive. The characteristics of the typical woman, however, do not conform to the expectations of an executive. As a result, the leadership potential of women is considered to be less pronounced. What is more, the actual leadership behaviour of women is judged much more critically. The influence of prevailing stereotypes on women's career prospects has been confirmed by numerous empirical studies.[463]

A job application experiment for a scientific position in the fields of biology, chemistry and physics conducted in the United States clearly demonstrated the relevance of stereotypes.[464] As part of this experiment, professors were supplied with identical application documents. The male and female professors reviewing the applications assessed those with a female first name as less competent than those with a male first name. The experiment showed that women would be less frequently hired, would receive a lower starting salary and would receive less support in their career development. In Germany, a number of companies have introduced anonymised application procedures as part of a pilot project initiated by the Federal Anti-Discrimination Agency. This has helped reduce the scope of discrimination.[465]

However, not all job application, appointment and promotion procedures can be carried out anonymously. It is therefore essential to overcome prevailing stereotypes. Box 15 describes two projects where this has been accomplished successfully.

In addition to stereotypes, gender-specific characteristics also play a role in salary and career-related differences. In comparison to men, women often avoid competitive situations and engage in competitive behaviour less often.[466] They are also more reluctant with respect to salary negotiations. A field experiment in the United States demonstrated that, in cases where a job advertisement does not specify whether wages are negotiable, men are more likely to address this issue than women.[467]

SWEDEN – LEADING IN INNOVATION PERFORMANCE AND EQUALITY B 4–6

Sweden is a leading country in two areas: in terms of innovation performance and in terms of gender equality.[468] On the EU's Innovation Union Scoreboard, Sweden repeatedly assumes one of the top positions; in the most recent ranking it is even ranked first. Sweden records an above-average share of women among undergraduate and PhD students in engineering sciences, with a share that is well above that of Germany. Moreover, Sweden has been actively promoting gender equality for many years. These efforts have taken shape in numerous policy areas and have led to a high level of labour force participation of women.

Sweden particularly excels in terms of reconciling work and family life. In addition to an extensive range of public childcare facilities, Sweden has a parental leave model that provides incentives for integrating fathers into childcare. It includes an means-tested parental allowance (amounting to 80 percent of the last salary), a quota of parental leave days exclusively allocated to fathers (60 days), as well as a gender equality bonus, i.e. families that divide their parental leave on equal terms will receive an additional bonus. Besides this, the Swedish model is characterised by a high degree of flexibility as the duration of parental leave is calculated on the basis of days, and not on the basis of weeks or months.

The Swedish tax system is also designed to promote gender equality. As early as 1971, Sweden introduced individual taxation. In contrast to household-based taxation, individual taxation provides more incentives for both spouses to pursue employment. Yet, the Swedish tax system also contains tax allowances and transfer payments, e.g. for children or house building, that are calculated on the basis of the household income.

Working hours in Sweden's research system are also family-friendly, and working overtime is not very common. In contrast, Germany's and Austria's working

BOX 15

Ways of overcoming stereotypes

A project conducted in India illustrates the relevance of stereotypes and ways of challenging them. As part of a constitutional amendment, 30 percent of randomly selected villages had to allocate the position of chief councillor to a woman, i.e. only female candidates were allowed to apply. The subsequent elections – which did not provide for a gender quota – showed that those villages that had gained experience with female chief councillors would more frequently vote for women than those villages where previously only men had held leadership positions. The reason for this is that the perception of the competence of female politicians had altered. This example illustrates the role of stereotypes, but also the fact that stereotypes can be overcome. Prior to the introduction of the quota, voters had assessed the competence of female politicians as being significantly lower than that of male politicians – even though the basis for evaluation had been the same. However, once voters had gained experience with female politicians in leadership roles, they rectified their earlier assessment regarding the competence and effectiveness of female politicians. Moreover, notions of the role of women in the public and private sphere had changed. In addition, the gender quota also had a positive impact on girls' educational decisions: in those villages with a gender quota, girls were more likely to strive for professions that require training. Also, the parents of girls were more open to the idea of their daughter receiving further training.[469]

Stereotypes are by no means confined to developing countries or rural environments. At Harvard Business School it could be observed that female students were falling behind their male fellow students, despite having had the same test results prior to taking up their degree courses. Furthermore, Harvard Business School experienced major difficulties in appointing and retaining female professors. These issues were attributed to the school's extremely male-dominated environment, which made it difficult for women to assert themselves. To address these issues, in 2011, Harvard Business School launched a project that aimed to counteract the disadvantage faced by women. The project comprised a revision of the academic curriculum and aimed at challenging social rules and practices. For example, classes were recorded by stenographers in order to monitor whether grades were subject to gender bias. Furthermore, female students were provided with training courses on demeanour, language and learning behaviour. The success of these measures was confirmed with the graduation of the first cohort of students who had benefitted from these measures: women participated more actively in class, they achieved better grades, they received more academic awards, and the atmosphere was perceived as more agreeable.[470]

culture in the area of research is characterised by permanent availability and long working hours or attendance times, respectively. Only 5 percent of researchers in Sweden state that they work more than 41 hours per week – as opposed to 50 percent of researchers in Austria and 33 percent of researchers in Germany.[471]

Gender awareness is also promoted at corporate level: every three years, businesses are required to collect and analyse data on disparities in income between women and men. Companies with 25 or more employees are obliged to provide equality plans with information on clear timeframes and planned measures. Companies are required to issue regular reports explaining and evaluating the implementation of such measures.[472]

Equal opportunities constitute a key objective of the Swedish education policy, which aims to counteract gender-specific career and study choices. Measures include e.g. company visits or mandatory internships in occupational fields that do not comply with traditional gender-specific domains. Moreover, the Swedish education system continuously provides entry points for natural science/technical training pathways, e.g. in the form of special one-year courses in which the requirements for subsequent natural science/technical degree courses are taught. These offers are primarily taken up by young women and youths from socially disadvantaged groups. The entry points are considered to be the main reason why more female students – in relation to all students – choose a degree course in natural science/technical subjects when compared with other countries.

Overall, the example of Sweden demonstrates that one policy instrument alone does not suffice to successfully promote women. To achieve this, a comprehensive approach applied to manifold political and social domains is required.

B 4–7 RECOMMENDATIONS – IMPROVING THE STRUCTURAL FRAMEWORK

Greater participation of women in the innovation system will increase the innovative power of Germany as a business location. Both academic and industrial R&D will benefit from new ideas and different perspectives and approaches. Greater awareness of the different needs and preferences of customers and users – of which 50 percent are women – will facilitate the development of customised solutions and applications.

In order to make better use of this potential, the Expert Commission has identified a need for action in the following areas.

Attracting women and girls to natural sciences

The Expert Commission reiterates its recommendation from its previous Annual Report to put particular emphasis on the mathematical and technical education of girls at the school level. Schools need to foster an interest in and enthusiasm for mathematical and technical issues among female pupils, thereby creating an improved skill basis in order to facilitate the decision to enrol in engineering degree courses at a later stage. To achieve these goals, the government has to provide adequate resources for high-quality teaching in STEM subjects.[473] The Expert Commission would like to stress that investments in education need to be viewed in conjunction with Germany's innovative capacity.

In the field of life sciences, attempts to stir girls' interest in these fields of study have been successful. However, problems occur at higher career levels, which shall be addressed in the following.

Reconciling family and working life

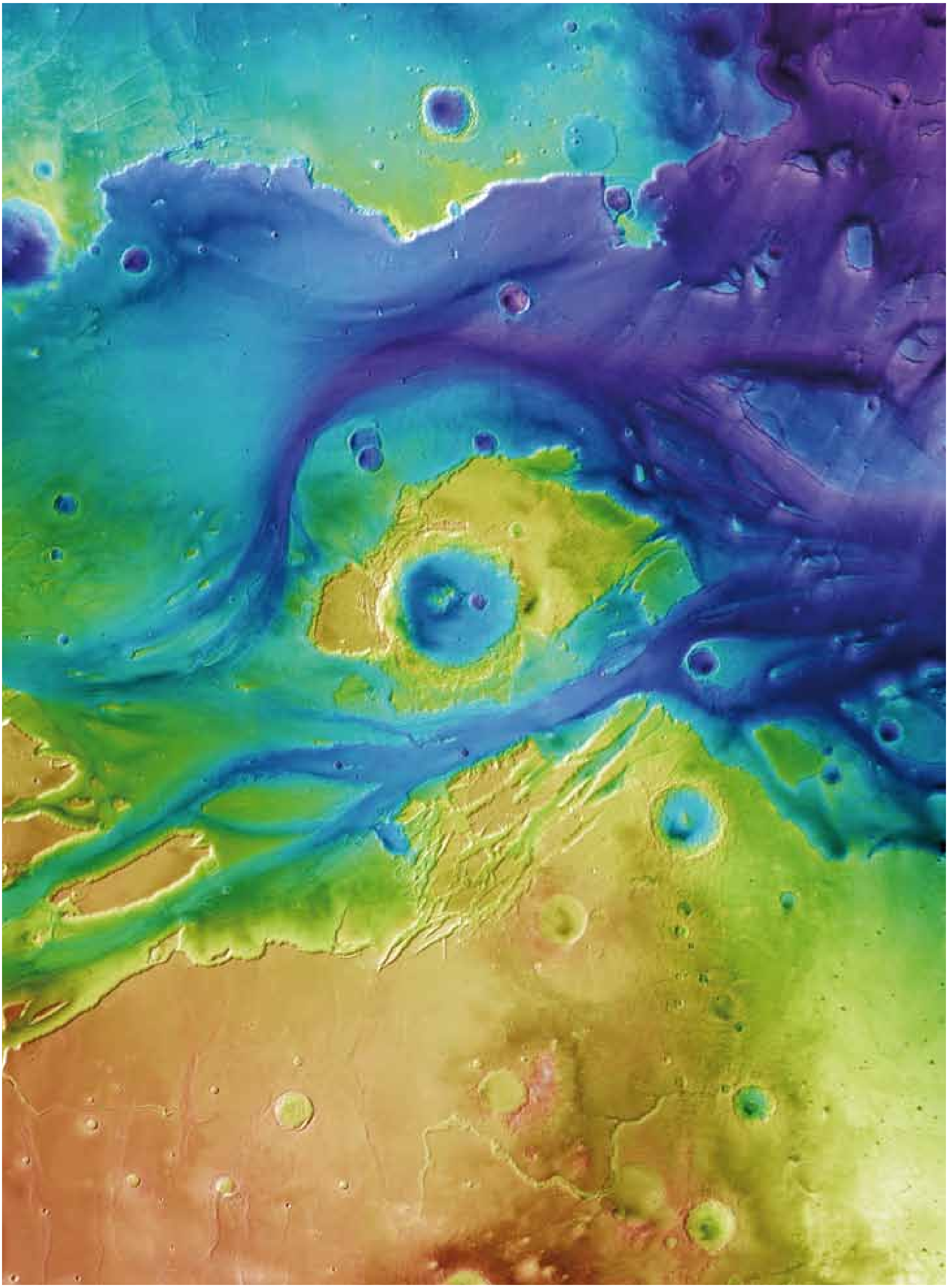
The Expert Commission recommends swiftly advancing the expansion of childcare facilities and all-day schooling in particular. This will make it less difficult for women to pursue employment and create necessary long-term incentives for making greater use of the labour force potential of women – also in engineering professions.[474]

The Expert Commission further recommends measures to support family-friendly working conditions at the corporate level. The Scandinavian countries can serve as a model in this respect. These countries perform very well in terms of distributing family work more evenly between men and women and in ensuring a high labour force participation of women – also in STEM professions and leadership positions.[475] In this context, decisive factors include flexible working time models, staggered hours of work, home office options as well as the departure from attendance as a performance indicator. Most notably, employees must be provided with more flexibility in terms of varying or increasing their working hours after a temporary period of part-time employment.

In the view of the Expert Commission, incentives for well-educated women to exit the labour market should be eliminated. These include incentives resulting from the tax system (spousal joint tax declarations, *Ehegattensplitting*) and the childcare allowance *(Betreuungsgeld)* that is currently in place.

Reducing stereotypes that hinder career progress

To overcome discrimination against women stemming from stereotypical gender roles, businesses and research institutions should establish internal processes to ensure that their recruitment and selection procedures, as well as their promotion decisions and decisions on filling leadership positions do not lead to unintended gender bias.[476] In this context, it is essential to standardise recruitment and promotion procedures, to ensure the anonymity of application documents and to regularly raise awareness among those in charge of HR decisions.[477] Public authorities could lead here by implementing relevant measures in public administration, while also working towards implementing such structures in the tertiary



Topography of the lower reaches of Kasei Valles.

Vertical plan view of the crater Becquerel.

education sector, at research institutions and in the private sector.

Target agreements and quotas

The Federal Government's coalition agreement provides for the introduction of a gender quota of 30 percent for non-executive boards of fully co-determined and listed companies. The Expert Commission welcomes this initiative. However, to ensure that quotas or target agreements are actually met, clear-cut penalties will have to be enforced in those cases where objectives are not achieved. This applies to target agreements for executive staff at companies and research institutions. If senior managers fail to recruit a sufficient number of women, this will have to affect their performance review and, ultimately, their financial compensation. In addition, legal regulations will have to provide for penalties, thereby setting sufficient incentives for companies to achieve the objectives.

While it is essential to increase the share of women on non-executive boards, increasing the share of women on executive boards should not be neglected either. As statutory enforcement options are lacking, increased participation of women on executive boards should be promoted within the framework of the Corporate Governance Code.

Finally, the Federal Government should also increase the share of women in leadership positions in public administration.

STRUCTURE AND TRENDS

C

C STRUCTURE AND TRENDS

OVERVIEW

Performance records on Germany as a research and innovation location constitute an integral part of the Expert Commission's annual reports. Records are based on a number of indicators that allow conclusions on the dynamics and performance of Germany's research and innovation system. For the sake of clarity, indicators have been divided into eight thematic sets that cover main areas of the national research and innovation system. These are: 1) education and qualification, 2) research and development, 3) innovation behaviour in the private sector, 4) funding of research and innovation, 5) new enterprises, 6) patents, 7) scientific publications, as well as 8) production, value added and employment.

Based on this set of indicators, the performance of the German research and innovation system is presented in intertemporal and international comparison with important competing countries.[478] Individual indicators are also employed at federal state level to identify differences in performance within Germany. Most of the indicators have been drawn from the Studies on the German Innovation System commissioned by the Expert Commission. In addition to the indicators listed above, these studies also offer further comprehensive data and information. All of the studies can be accessed and downloaded on the Expert Commission's website. The same applies to all figures, tables and related data presented in the Report.

C 1 EDUCATION AND QUALIFICATION

Investment in education and a high level of qualification strengthen a country's capacity for innovation and economic growth in the medium and long term. The indicators listed under section C 1 provide information on the level of qualification, as well as an overview of Germany's strengths and weaknesses as an innovation location. To facilitate the assessment of Germany's performance at an international level, findings are presented in comparison with other industrialised countries.

C 2 RESEARCH AND DEVELOPMENT

Research and development processes are essential for developing new products and services. As a rule, a high R&D intensity has positive effects on competitiveness, growth and employment. R&D investments and activities of companies, universities and governments therefore provide an important source of information for assessing a country's technological performance. Section C 2 gives insights into Germany's R&D activities in international comparison, the expenditure at federal state level and sectoral research intensities in the economy.

C 3 INNOVATION BEHAVIOUR IN THE PRIVATE SECTOR

Innovation activities by firms aim at creating competitive advantages. In the case of product innovations, a new or improved good is launched on the market. By definition, this good differs from any other goods previously sold on the market. The launch of a new or improved manufacturing process, however, is referred to as process innovation. Section C 3 shows the innovation behaviour in the German economy in international comparison based on innovation intensities in industry and knowledge-intensive services, as well as profit shares generated with new products.

FUNDING OF RESEARCH AND INNOVATION C 4

The financing of business and, in particular, R&D activities is a key challenge especially for young, innovative enterprises. As these companies initially generate little or no revenue self-financing is often not an option. Debt financing is also an issue as it is difficult for investors such as banks to assess the success probability of an innovative start-up business. Alternative ways of corporate financing include funding from equity capital or venture capital firms, as well as financing from public sources. Section C 4 describes the availability of venture capital and public R&D funds in Germany and in international comparison.

NEW ENTERPRISES C 5

With their innovative products, processes and business models, entrepreneurs – especially those in research and knowledge-intensive industries – are challenging incumbent companies. The creation of new enterprises and the market exit of unsuccessful or formerly successful companies assures innovation competition for the best solutions. The business dynamics described in section C 5 are therefore an important aspect of structural change. New enterprises open up markets and facilitate the breakthrough of innovative ideas – especially in new fields of technology, emerging demand, and in the early phase of the transfer of scientific knowledge to the development of new products and processes.

PATENTS C 6

Patents are intellectual property rights for new technical inventions. Thus, patents often provide the basis for exploiting innovations on the market, while at the same time supporting coordination as well as knowledge and technology transfer between the stakeholders involved in the innovation system. Section C 6 presents the patent activities of selected countries, while also displaying the extent to which these countries have specialised in the fields of high-value technology and cutting-edge technology.

SCIENTIFIC PUBLICATIONS C 7

The steady creation of new knowledge strongly depends on the performance of the respective research and science system. Based on bibliometric data, section C 7 depicts Germany’s performance on this matter in international comparison. The performance of a country is determined on the basis of its researchers’ publications in scientific journals. The perception and relevance of these publications is measured by the number of citations.

PRODUCTION, VALUE ADDED AND EMPLOYMENT C 8

The proportion of labour input and value added in research and knowledge-intensive sectors reflects their economic importance in a country and allows conclusions on its technological performance. Section C 8 depicts the dynamics in value added and productivity in research-intensive industries and knowledge-intensive services in Germany and in international comparison. This section also provides insights into Germany's ranking in terms of global trade in research-intensive goods and knowledge-intensive services.

C 1 EDUCATION AND QUALIFICATION

The proportion of gainfully employed persons with tertiary education qualifications (ISCED 6, ISCED 5A and 5B) of the total labour force amounts to 29 percent in Germany (C 1–1). When including the level of ISCED 4 – which comprises equivalent further education qualifications and accounts for a total of 8.2 percent of Germany's labour force – the share of gainfully employed persons with tertiary or equivalent qualifications was at 37.3 percent in 2012 and thus higher than in the previous year (36.6 percent).

This trend is attributable to the fact that Germany's university entry rate has continuously increased in recent years (C 1–2). Between 2001 and 2011 alone, the rate of persons with higher education entrance qualification in Germany increased from 32 to 46 percent. Moreover, the number and the proportion of individuals eligible for tertiary education in Germany has grown steadily ever since 1970 (C 1–3). With around 506,500 school-leavers with higher education entrance qualification, the number of potential tertiary education entrants reached its peak in 2011, representing a share of 57 percent of school-leavers per cohort. In 1970, this proportion was still at only 11 percent, and in 1980 at around 22 percent.

However, as a result of Germany's ageing population, the number of persons with higher education entrance qualification is expected to decrease from 2014. Yet, according to the most recent estimates, the number will still be well above 400,000 until the year 2025. It is to be expected that the proportion of school-leavers with higher education entrance qualification of all school-leavers will amount to around 60 percent.

As a result of the sharp increase in the number of first-year students, the number of university graduates in Germany has also increased since 2007. With 309,621 first-time graduates, the year 2012 marked a new record high (C 1–4). Since 2000, the number of first-time graduates thus increased by approximately 75 percent. At the same time, however, graduate numbers within the STEM subject group developed very differently over a longer period of time. Most recently (since 2012) the subjects group of mathematics / natural sciences experienced a 2.7 percent decline in the number of graduates (reaching a proportion of 15.6 percent), while the subjects group of engineering displayed a sharp rise (8.3 percent) in the number of graduates, reaching a proportion of 19.5 percent.

Germany continues to be successful in attracting international university students. In the winter semester of 2012 / 2013 approximately 282,200 foreign students were enrolled at German tertiary education institutions (C 1–5). The total number of foreign students has increased by 6.4 percent compared to the previous year and has thus reached a new high. Foreign students account for approximately 11 percent of all students enrolled in Germany.

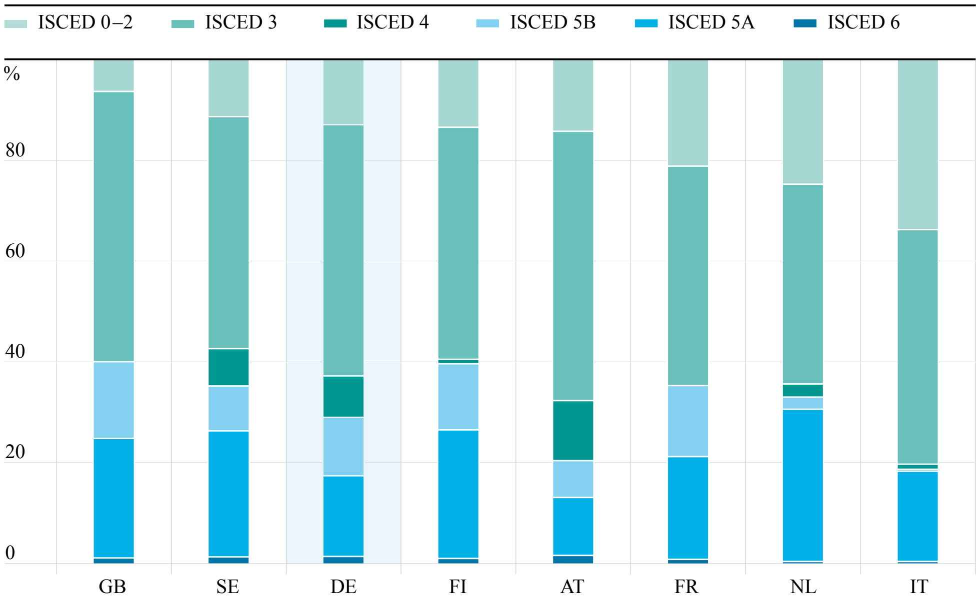
Participation in further training of persons of working age (15 to 64 years) remained at 4.8 percent and was thus unchanged in 2012 compared to 2011. Broken down by employment status, participation in further training was at the highest among gainfully employed persons (5.8 percent) and at the lowest among economically inactive persons (1.7 percent). Since 2008, a slight negative trend in training participation can be observed, which, again, has been most pronounced among economically inactive and unemployed persons.[479]

Qualification level of the workforce in selected EU countries in 2012 (figures in percent)

C 1–1

DATA DOWNLOAD

The classification of qualification levels is based on the International Standard Classification of Education (ISCED).[480]
ISCED 0–2: pre-primary, primary and lower secondary education
ISCED 3: qualification to study at a university of applied science or completion of an apprenticeship
ISCED 4: qualification to study at a university of applied sciences/university an completion of apprenticeship
ISCED 5B: master craftsman or technician training, or an equivalent degree from a university of applied sciences
ISCED 5A: degree from a tertiary education institution
ISCED 6: completion of doctoral degree



Source: Eurostat, European Labour Force Survey. Calculations by NIW. In: Baethge et al. (2014).

Share of new tertiary students in the relevant age group in selected OECD countries (figures in percent)

C 1–2

DATA DOWNLOAD

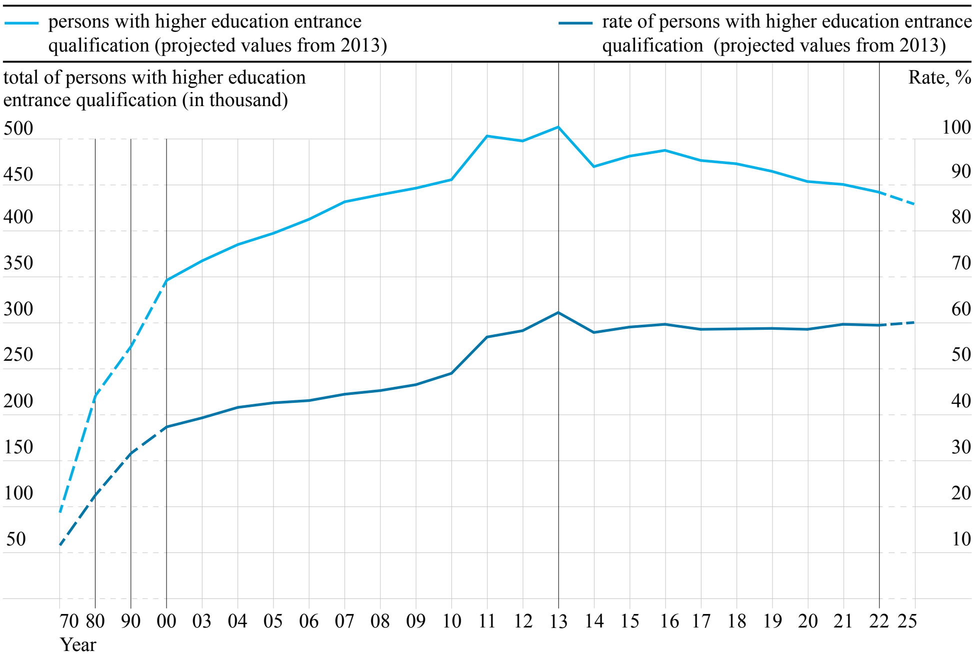
Entrance rate: proportion of newly enrolled students as a percentage of the population in the relevant age group. The entrance rate measures the extent to which demographic potential is exploited for the development of academic human capital.

OECD-Länder	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2011[1)]
Germany	32	35	36	37	36	35	34	36	40	42	46	40
France	37	37	39	–	–	–	–	–	–	–	39	–
Great Britain	46	48	48	52	51	57	55	57	61	63	64	–
Japan	37	39	40	40	41	45	46	48	49	51	52	–
Korea	49	–	47	49	54	59	61	71	71	71	69	–
Sweden	69	75	80	79	76	76	73	65	68	76	72	59
Switzerland	33	–	38	38	37	38	39	38	41	44	44	33
USA	42	64	63	63	64	64	65	64	70	74	72	–
OECD average	48	52	53	53	54	56	56	56	59	61	60	–
China	–	–	–	–	–	–	–	–	17	17	19	–

[1)] Adjusted rate without international first-year students.
Sources: OECD (ed.): Education at a Glance, OECD Indicators, various years. In: Baethge et al. (2014).

C 1–3 **School-leavers qualified for higher education in Germany 1970 to 2025, projection from 2013**

DATA DOWNLOAD



Source (actual values): *Statistisches Bundesamt* (various years), Source (projected values): statistical publications of the Conference of Ministers of Education and Cultural Affairs *(Kultusministerkonferenz)*. In: Baethge et al. (2014).

Persons with higher education entrance qualification: school-leavers who have obtained entitlement to enter general or subject-specific tertiary education at a university or a university of applied sciences. Entrance rate: proportion of newly enrolled students as a percentage of the population in the relevant age group.

C 1–4 **Number of first-time graduates and subjects structure rates**

DATA DOWNLOAD

	2000	2005	2007	2009	2010	2011	2012
Total number of graduates	**176,654**	**207,936**	**239,877**	**287,997**	**294,330**	**307,271**	**309,621**
Percentage of women	45.6	50.8	51.8	51.7	52.1	51.4	51.3
Percentage of university graduates	64.3	60.8	62.4	62.0	62.0	62.1	61.3
Linguistics, cultural studies	**29,911**	**35,732**	**43,827**	**53,003**	**54,808**	**56,140**	**55,659**
Percentage for subject group	16.9	17.2	18.3	18.4	18.6	18.3	18.0
Law, business and social sciences	**62,732**	**76,566**	**85,838**	**101,391**	**102,315**	**105,589**	**105,024**
Percentage for subject group	35.5	36.8	35.8	35.2	34.9	34.4	33.9
Human medicine/ healthcare sciences	**10,620**	**11,817**	**13,358**	**15,142**	**15,222**	**15,686**	**15,856**
Percentage for subject group	6.0	5.7	5.6	5.3	5.2	5.1	5.1
Agriculture, forestry, nutrition sciences	**4,761**	**5,312**	**5,661**	**6,787**	**6,215**	**6,563**	**6,405**
Percentage for subject group	2.7	2.6	2.4	2.3	2.1	2.1	2.1
Art and art-related subjects	**7,630**	**9,678**	**10,399**	**11,541**	**11,820**	**12,525**	**12,866**
Percentage for subject group	4.3	4.7	4.3	4.0	4	4.1	4.2
Mathematics, natural sciences	**21,844**	**30,737**	**38,417**	**47,782**	**48,561**	**49,593**	**48,231**
Percentage for subject group	12.4	14.8	16	16.6	16.5	16.1	15.6
Engineering sciences	**35,725**	**34,339**	**38,065**	**47,004**	**49,860**	**55,631**	**60,259**
Percentage for subject group	20.2	16.5	15.9	16.3	16.9	18.1	19.5

Source: *Statistisches Bundesamt,* as well as research in HIS/ICE. In: Baethge et al. (2014).

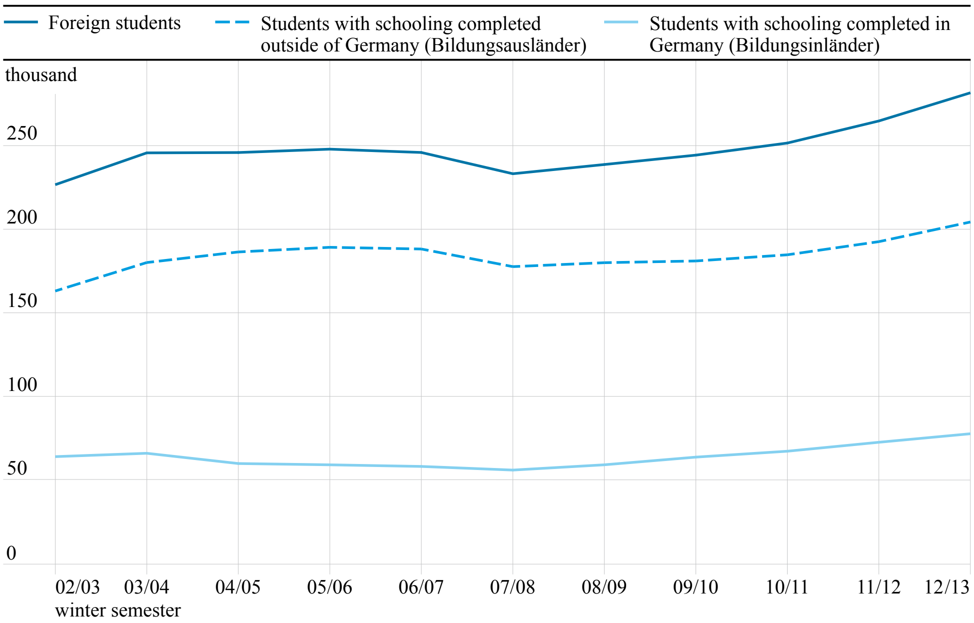
First-time graduates and subjects structure rate: the subjects structure rate indicates the percentage of first-degree graduates who have completed their studies in a particular subject or group of subjects. First-time graduates are persons who successfully complete a first degree.

Foreign students at German tertiary education institutions

C 1–5

DATA DOWNLOAD

Foreign students are persons without German citizenship. These can be divided into students who obtained their higher education entrance qualification in Germany *(Bildungsinländer)*, and students who obtained their higher education entrance qualification abroad *(Bildungsausländer)*.



Source: *Statistisches Bundesamt,* as well as research in HIS/ICE. In: Baethge et al. (2014).

Further training according to employment status and qualification level
(figures in percent)

C 1–6

DATA DOWNLOAD

Further education rate: proportion of persons who participated in a further education measure within four weeks prior to the time of the survey.

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Gainfully employed persons	**6.8**	**6.3**	**5.9**	**6.0**	**6.1**	**5.9**	**5.8**	**5.8**	**5.8**
low (ISCED 0–2)	3.9	2.4	2.1	1.9	2.1	1.9	1.8	1.7	1.6
medium (ISCED 3–4)	5.0	4.7	4.5	4.6	4.7	4.5	4.5	4.4	4.3
high (ISCED 5–6)	12.1	12.1	11.5	11.8	11.8	11.0	10.5	10.6	10.6
Unemployed persons	**3.9**	**3.2**	**3.4**	**3.6**	**4.3**	**4.5**	**4.1**	**3.6**	**3.6**
low (ISCED 0–2)	2.4	2.3	2.4	2.7	2.9	3.1	3.0	2.7	2.7
medium (ISCED 3–4)	3.7	3.0	3.2	3.5	4.5	4.2	4.0	3.5	3.4
high (ISCED 5–6)	7.8	6.1	7.0	7.1	7.6	9.1	7.1	6.2	6.4
Inactive persons	**2.8**	**2.2**	**2.1**	**2.0**	**2.2**	**2.1**	**2.1**	**1.9**	**1.7**
low (ISCED 0–2)	1.7	1.4	1.4	1.4	1.5	1.6	1.5	1.5	1.5
medium (ISCED 3–4)	3.5	2.5	2.2	2.2	2.3	2.2	2.1	1.8	1.6
high (ISCED 5–6)	4.6	4.3	4.4	4.0	4.6	3.9	3.8	3.5	3.0

All figures are provisional. Re. ISCED cf. C 1–1
Total population: all persons from the age of 15 to 64 years (excluding school-going juveniles, vocational trainees and students)
Source: European Labour Force Survey (special evaluation). Calculations by NIW. In: Cordes et al. (2014).

C 2 RESEARCH AND DEVELOPMENT

With a research intensity of 2.98 percent in 2012, Germany recorded the highest R&D intensity to date, while also reaching its own stated target of three percent.[481] In spite of this success, Germany continues to lag behind such countries as Korea (4.36 percent), Japan (3.34 percent) and Sweden (3.41 percent). The United States' R&D intensity increased slightly in 2012 to 2.79 percent, but did not regain the level of 2009 (2.82 percent). Overall, the United States account for approximately 41 percent of R&D expenditure within the OECD.

The budgets for civil R&D (C 2 – 2) show that public expenditure on R&D has increased in the last ten years in all of the comparative countries. The development during the period 2002 – 2012, however, is heterogeneous. R&D investment in France increased only slightly up until 2008 and even decreased over some of the years. Sweden, Switzerland and, especially, Korea continuously increased their R&D efforts over the surveyed period. In the United States, public investment in R&D increased only slowly between 2002 and 2008 but was stepped up considerably as part of the 2009 stimulus programme.

The distribution of gross domestic expenditure on R&D by performing sector (C 2 – 3) developed in disparate ways in the comparison countries between 2001 and 2011. It is noteworthy that in the Asian economies, the private sector's share in R&D expenditure increased between 2001 and 2011, while the European economies and the United States recorded a decline. In Germany, the private sector's share in gross domestic expenditure on R&D decreased from 70 percent in 2001 to 68 percent in 2011.

The figure on the German federal states' R&D intensity (C 2 – 4) shows that there are no significant differences between the eastern, northern and southern German federal states with regard to public R&D facilities. However, the R&D intensity of the private sector shows major differences across Germany's federal states. The states of Bavaria, Baden-Württemberg and Hesse recorded by far the highest values of all federal states. In Baden-Württemberg and Hesse, the R&D intensity of the private sector has also increased significantly compared to 2001.

The share of Germany's public sector's funding of private R&D activities is low when compared to other countries. The breakdown of private internal R&D expenditure by source of funding (C 2 – 5) for the year 2011 shows that the state financed approximately 4 percent of the total R&D activities conducted by private businesses. Two years earlier this share amounted to 3.6 percent, and four years earlier it had amounted to 3.1 percent. Public R&D funding is particularly important for small enterprises: in 2011, the government's share of financing for companies with less than 100 employees amounted to almost 15 percent.

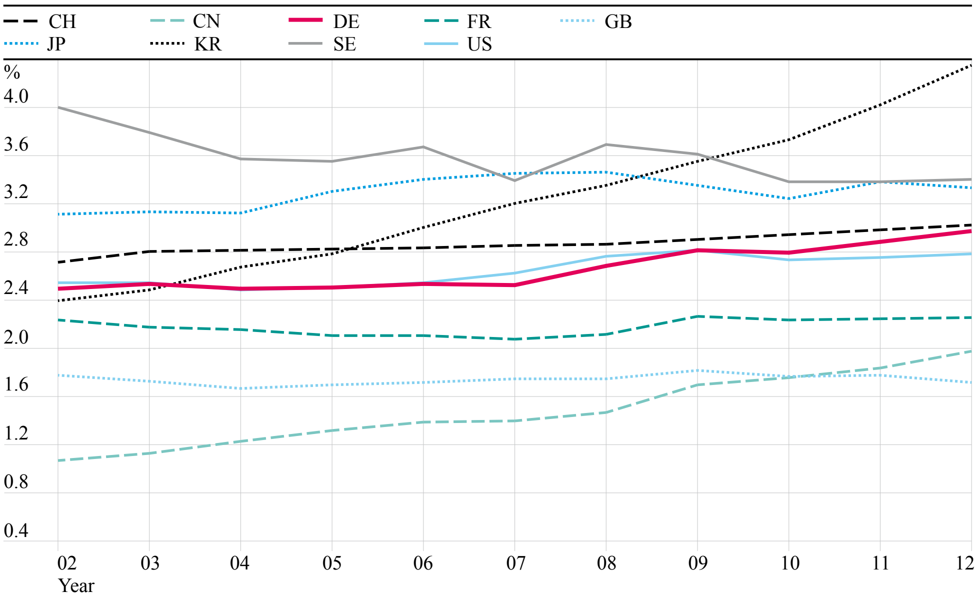
The breakdown of R&D expenditure according to industry, as measured by internal R&D expenditure relative to revenue from domestic products (C 2 – 6), shows that most industries once again increased their R&D intensity in 2012 compared to the preceding year (2011). Only in the pharmaceutical industry and in other transport equipment did R&D intensity experience a slight downturn. Overall, the manufacturing sector's R&D intensity increased to 3.2 percent in 2012 compared to 3.1 percent in the preceding year.

R&D intensity in selected OECD countries and China
(figures in percent)

C 2–1

DATA DOWNLOAD

R&D intensity: share of expenditure on research and development of an economy's gross domestic product.



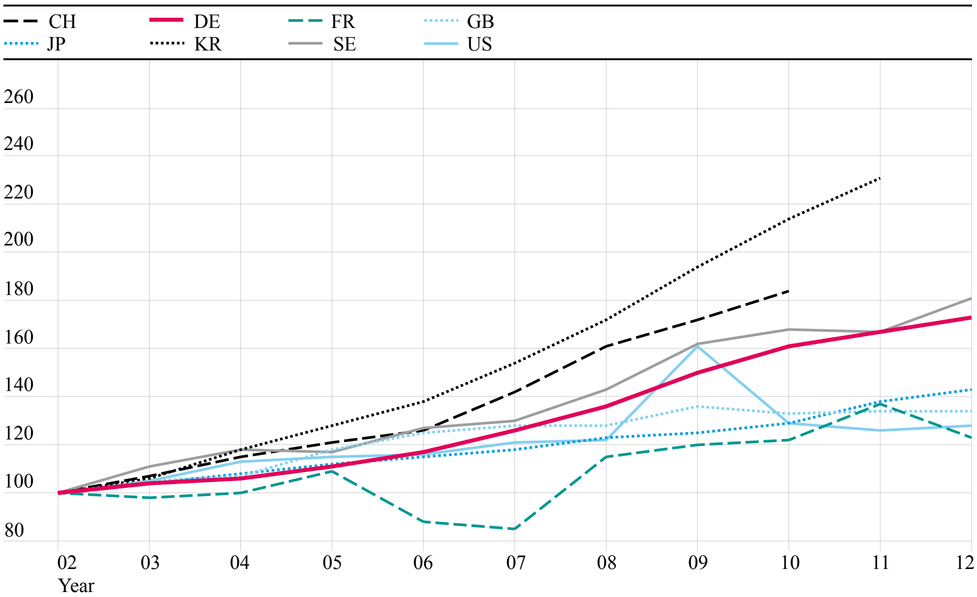
Source: OECD, *SV Wissenschaftsstatistik*.
Calculations and estimates by NIW. In: Schasse et al. (2014).

State budget estimates for civil R&D

C 2–2

DATA DOWNLOAD

R&D budget estimates: budget resources available for the financing of R&D as specified in the state budget.



Index: 2002 = 100, data partially based on estimates.
Source: OECD, EUROSTAT. Calculations and estimates by NIW. In: Schasse et al. (2014).

C 2–3 **Distribution of gross domestic expenditure on R&D (GERD) by performing sector 2001 and 2011**

DATA DOWNLOAD

Gross domestic expenditure on R&D (GERD) refers to expenditure on research and development in the private sector, higher education sector and the public sector.

Countries	2001					2011				
	GERD in million USD[1]	of which … was performed by … (in %) private sector	higher education sector	public sector	not defined	GERD in million USD[1]	of which … was performed by … (in %) private sector	higher education sector	public sector	not defined
DE	54,426	69.9	16.4	13.7	–	93,987	67.7	17.8	14.5	–
FR	35,804	63.2	18.9	16.5	1.4	51,891	63.4	21.2	14.1	1.2
GB	29,179	65.5	22.7	10.0	1.8	39,627	61.5	26.9	9.3	2.4
JP	103,718	73.7	14.5	9.5	2.3	146,537	77.0	13.2	8.4	1.5
KR	21,259	76.2	10.4	12.4	1.0	59,890	76.5	10.1	11.7	1.6
SE	10,374	77.5	19.6	2.8	0.1	13,216	69.3	26.0	4.3	0.3
CH[2]	5,766	73.9	22.9	1.3	1.9	10,525	73.5	24.2	0.7	1.6
US	278,239	72.6	12.1	11.3	4.0	415,193	68.3	15.2	12.1	4.3
CN	31,744	60.4	9.8	29.7	–	208,172	75.7	7.9	16.3	–

[1] 2000 instead of 2001, and 2008 instead of 2011. [2] GERD in USD according to PPP.
Not defined: share of GERD not explicitly performed in the “private”, “higher education” or “public” sectors; this share is often included in the “public” sector.
Source: OECD, Eurostat (figures as of 13/11/2013), *SV Wissenschaftsstatistik.* In: Schasse et al. (2014).

C 2–4 **R&D intensity of Germany’s federal states between 2001 and 2011** (figures in percent)

DATA DOWNLOAD

R&D expenditure: share of the federal states’ R&D expenditure as a percentage of their GDP, according to performing sectors.

Federal states	2001 Total	2001 private sector	2001 public sector	2001 higher education sector	2011 Total	2011 private sector	2011 public sector	2011 higher education sector
Baden-Württemberg	3.86	3.05	0.40	0.41	5.08	4.10	0.43	0.55
Bavaria	3.07	2.46	0.24	0.37	3.15	2.41	0.30	0.44
Berlin	3.94	2.15	1.01	0.78	3.55	1.39	1.24	0.92
Brandenburg	1.47	0.54	0.65	0.28	1.68	0.54	0.78	0.36
Bremen	2.14	1.05	0.56	0.53	2.78	1.00	1.00	0.78
Hamburg	1.40	0.72	0.33	0.34	2.24	1.26	0.47	0.51
Hesse	2.37	1.92	0.15	0.30	3.01	2.35	0.23	0.44
Mecklenburg-West Pomerania	1.17	0.18	0.48	0.51	2.09	0.68	0.73	0.67
Lower Saxony	2.49	1.79	0.31	0.39	2.88	1.97	0.40	0.51
North Rhine-Westphalia	1.74	1.09	0.28	0.38	2.01	1.21	0.31	0.49
Rhineland-Palatinate	1.96	1.48	0.14	0.34	2.07	1.46	0.18	0.44
Saarland	1.02	0.38	0.22	0.42	1.49	0.54	0.43	0.52
Saxony	2.44	1.22	0.60	0.61	2.91	1.26	0.88	0.77
Saxony-Anhalt	1.28	0.34	0.40	0.54	1.49	0.43	0.57	0.49
Schleswig-Holstein	1.15	0.53	0.31	0.32	1.43	0.69	0.36	0.37
Thuringia	2.11	1.13	0.44	0.53	2.22	1.03	0.54	0.65
Germany	**2.47**	**1.73**	**0.34**	**0.41**	**2.89**	**1.96**	**0.42**	**0.51**

Source: *SV Wissenschaftsstatistik, Statistisches Bundesamt.*
Calculations by NIW. In: Schasse et al. (2014).

C 2–5

Internal R&D expenditure of companies according to source of funding, sectors, size, and technology categories 2011

DATA DOWNLOAD

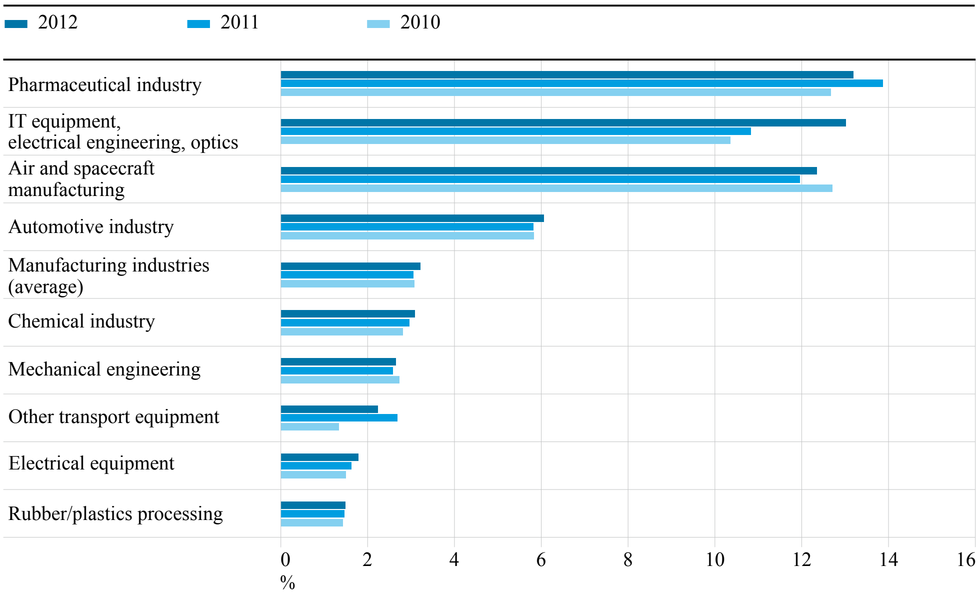
Internal R&D: research and development that is conducted inside the company, either for the company's own purposes or commissioned by a third party.

Internal R&D expenditure	Total	of which … was funded by			
		private sector	public sector	other domestic entities	foreign entities
	in EUR	in percent			
All companies active in research	**50,804,210**	**91.7**	**4**	**0.3**	**4**
Manufacturing industries	**43,733,376**	**93.1**	**3.2**	**0.2**	**3.6**
Chemical industry	3,296,674	95.3	2	–	2.7
Pharmaceutical industry	4,069,729	97.9	0.4	–	1.6
Plastics, glass and ceramic industries	1,224,873	93.3	2.5	0.5	3.8
Metal production and processing	1,242,073	80.5	7.4	–	12.1
Electrical engineering/electronics	8,165,077	94.8	3.2	0.1	1.9
Mechanical engineering	4,902,500	94.8	1.9	–	3.2
Vehicle equipment	18,914,281	91.5	4	0.3	4.3
Other manufacturing industries	1,918,170	91.2	3.3	–	5.5
Remaining sectors	**7,070,835**	**83.3**	**9.3**	**0.8**	**6.6**
less than 100 employees	2,864,072	81	14.9	0.5	3.6
100 to 499 employees	5,147,816	89.3	5.3	0.4	5
500 to 999 employees	3,027,362	87.5	7.1	0.1	5.3
1000 employees and more	39,764,960	93.1	2.8	0.2	3.8
Technology categories in industry					
Cutting-edge technology (> 9 percent of revenue expended on R&D)	13,092,505	90.6	6.9	–	2.5
High-value technology (2.5 – 9 percent of revenue expended on R&D)	25,497,475	95	1.3	0.2	3.6

Source: *SV Wissenschaftsstatistik.* In: Schasse et al. (2014).

C 2–6 **Internal R&D expenditure relative to revenue from domestic products 2010, 2011, 2012**

DATA DOWNLOAD



Figures net, without input tax
Source: *SV Wissenschaftsstatistik. Statistisches Bundesamt, Unternehmensergebnisse Deutschland.* Calculations by NIW. In: Schasse et al. (2014).

Internal R&D: research and development that is conducted inside the company, either for the company's own purposes or commissioned by a third party.

INNOVATION BEHAVIOUR IN THE PRIVATE SECTOR C 3

The Europe-wide Community Innovation Surveys (CIS) are conducted every two years and provide the database for the international comparison of the private sector's innovation performance (C 3 – 1).[482] Coordinated by Eurostat and based on a harmonised methodology, the CIS are conducted in all of the EU member states and a number of other European countries. The CIS comprise a largely unitary questionnaire and are directed at businesses with ten or more employees in the manufacturing industry and selected services sectors. The current analysis refers to the year 2010 (CIS 2010). In 2010, Germany's knowledge economy had an innovation intensity of 6.4 percent. The ratio was thus below that of Finland and Sweden, but still higher than that of Austria, France, the Netherlands and Italy.

Data on innovation behaviour in the German private sector as shown in Figures C 3 – 2 to C 3 – 4 are based on the Mannheim Innovation Panel (MIP), an annual innovation survey that has been conducted by the Centre for European Economic Research (ZEW) since 1993. Data from the MIP constitute the German contribution to the CIS. In addition to the data to be reported to Eurostat, the panel also collects data on businesses with five to nine employees.[483]

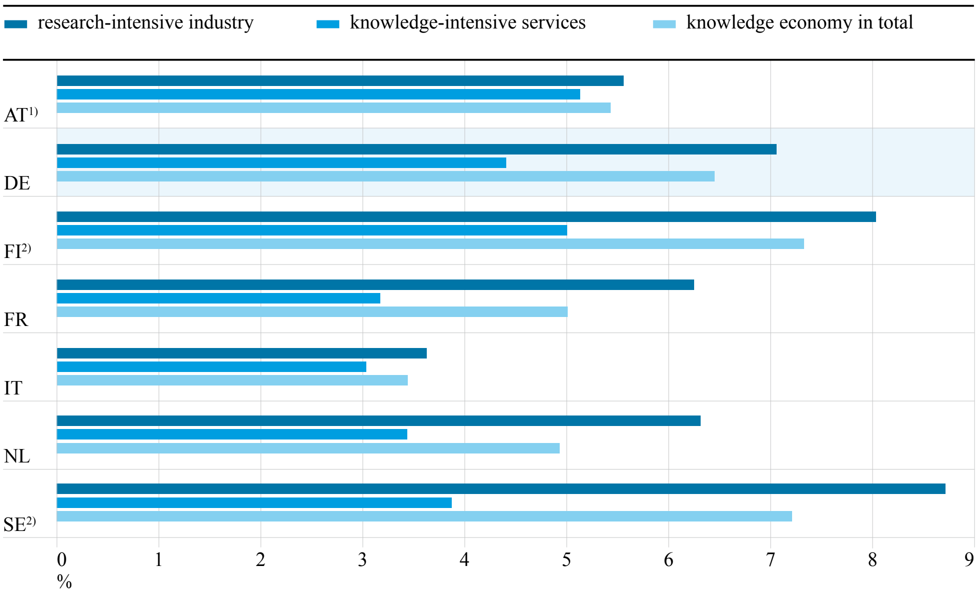
In the knowledge-intensive industry, innovation intensity (C 3 – 2) increased from 7.9 percent in 2011 to 8.3 percent in 2012, while innovation intensity in other industry and knowledge-intensive services stagnated.

The proportion of revenue generated with new products (C 3 – 3) decreased in the R&D-intensive industries to 34 percent as opposed to 36 percent in the previous year. Knowledge-intensive services experienced a sharp decline from 13 percent to 9 percent. In other industry and in knowledge-intensive services, the proportion of revenue generated with new products decreased by 1 percentage point, reaching 8 percent and 5 percent, respectively.

Standardisation is an important factor in the commercialisation of innovative technologies. At international level, standards are developed in the committees of the International Organization for Standardization (ISO). Through participation in these committees, a country can make a significant impact on global technical infrastructures (C 3 – 4).[484] German companies are more frequently involved in the work of the ISO than representatives of all other countries.

C 3–1 **Innovation intensity in 2010 in European comparison** (figures in percent)

DATA DOWNLOAD

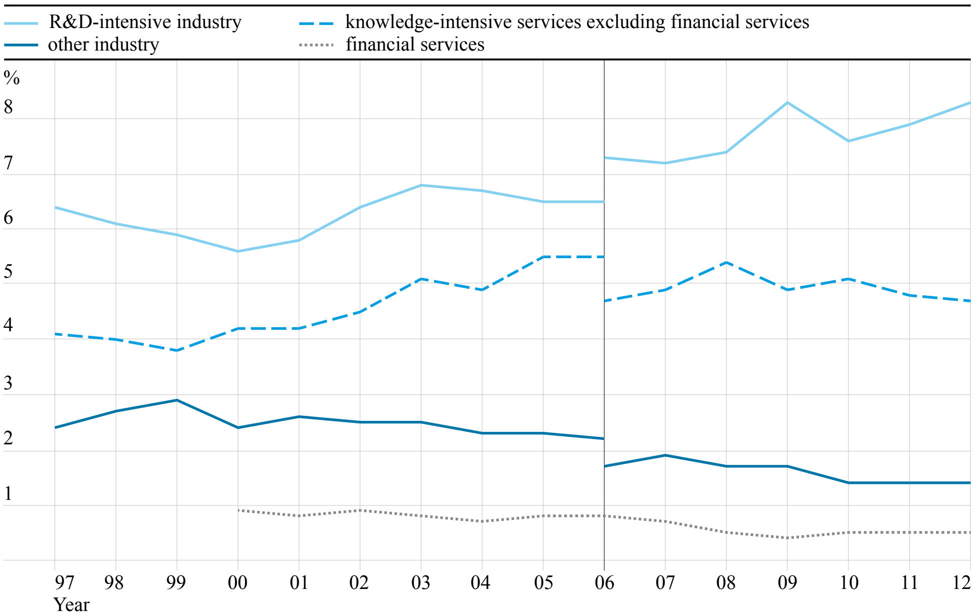


[1)]excluding pharmaceutical industry [2)]excluding pharmaceutical industry, including electrical engineering
Source: Eurostat, Community Innovation Surveys 2010. Calculations by ZEW.

Innovation intensity: companies' expenditure (on R&D, machinery and software, as well as external knowledge) relative to total revenue.

C 3–2 **Innovation intensity in Germany's industry and knowledge-intensive services**
(figures in percent)

DATA DOWNLOAD



Break in the time series in 2006. Figures for 2012 are provisional. Source: Mannheim Innovation Panel.
Calculations by ZEW.

Innovation intensity: companies' innovation expenditures relative to total revenue.

Solidified droplets of glass used to produce a sealant for solide oxide fuel cells (SOFC).

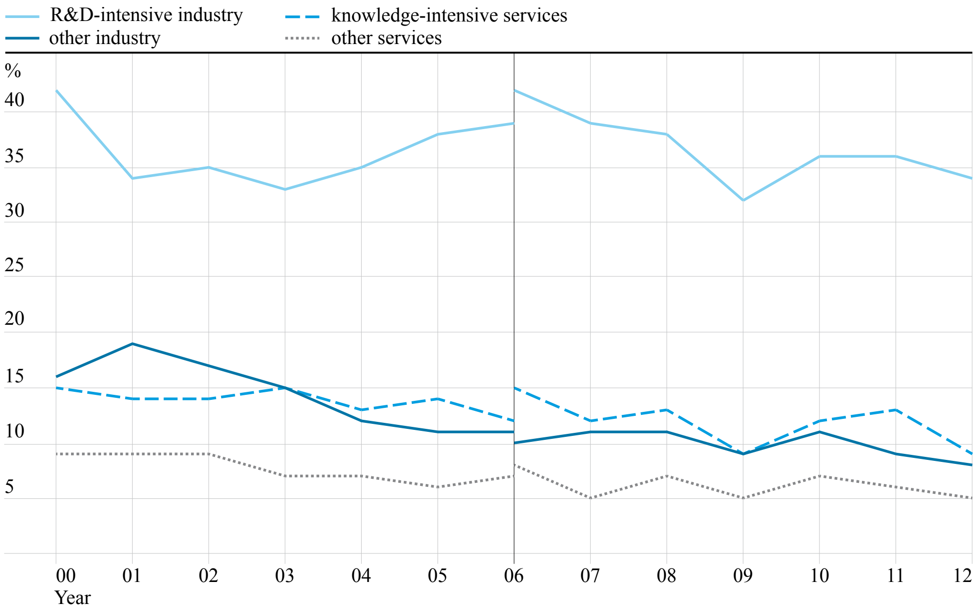
A drop of glass taken out of the induction furnace at Jülich's Central Technology Division, which has a temperature of 1,500 °C.

Proportion of revenue generated with new products in industry and knowledge-intensive services (figures in percent)

C 3–3

DATA DOWNLOAD

Proportion of revenue generated with new products: revenue from new or significantly improved products, newly introduced by innovative companies in the past three years, in relation to total revenue.



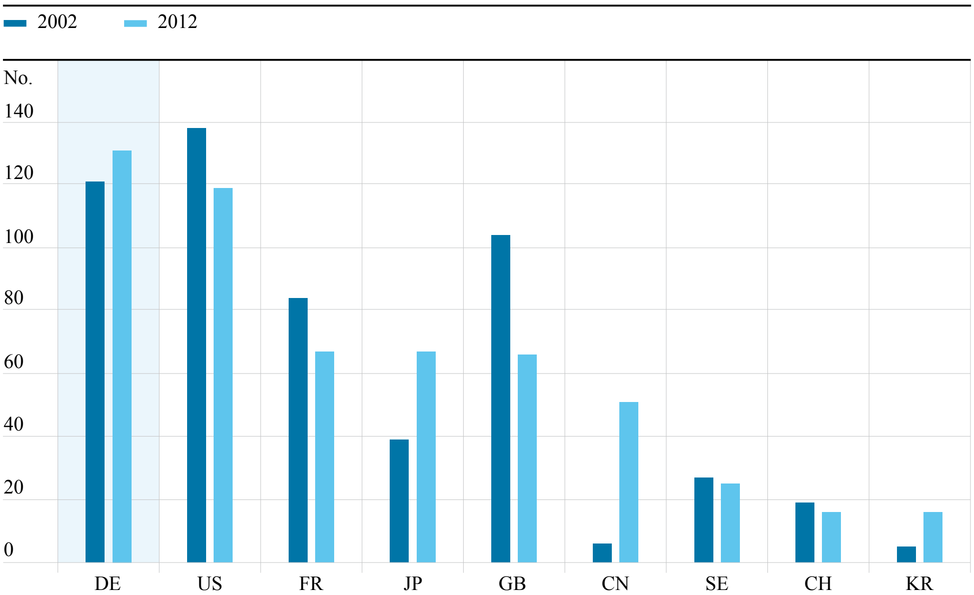
Break in the time series in 2006. Figures for 2012 are provisional.
Source: Mannheim Innovation Panel (MIP). Calculations by ZEW.

Number of assigned secretariats for technical committees and subcommittees of the International Organization for Standardization (ISO)

C 3–4

DATA DOWNLOAD

Standardisation: harmonisation of important characteristics of products, processes and services.



Source: ISO (2003:19), as well as http://www.iso.org/iso/annual_report_members_2012.pdf (last accessed on 10 January 2014). Own compilation.

C 4 FUNDING OF RESEARCH AND INNOVATION

With regard to public funding of research and development (R&D) in the private sector, a distinction is made between direct R&D funding (project funding) and funding through R&D tax credits.[485] Figure C 4 – 1 shows the share of direct and tax-related R&D funding in gross domestic product in selected countries. The bulk of resources allocated to project funding goes into application-oriented research, where project funding is often directed at specialised programmes that aim to promote specific technologies. However, when it comes to funding programmes that are not specific to individual technologies, the government does not exert influence on the nature or contents of the technologies funded. R&D tax credits represent an indirect form of R&D funding. This means that companies receive tax credits in proportion to the amount of their R&D expenditure. From an economic point of view, this lowers the marginal cost of performing R&D activities. While this instrument is available to businesses in most of the OECD countries, Germany does not make use of this form of funding yet. In many of the OECD countries, the share of R&D funding via tax credits already exceeds the share of direct public funding.

Financing constitutes a major challenge for many innovative companies – not only in the start-up phase, but also in the growth phase. Internal financing of investments and current expenditure is rarely an option as these companies initially generate only little or no revenue. The borrowing of outside capital in the form of bank loans is an issue as it is difficult for banks to assess the company's prospects of success. Therefore, young, innovative enterprises can often only establish themselves on the market with the help of private investors who provide venture capital during the start-up and growth phases.

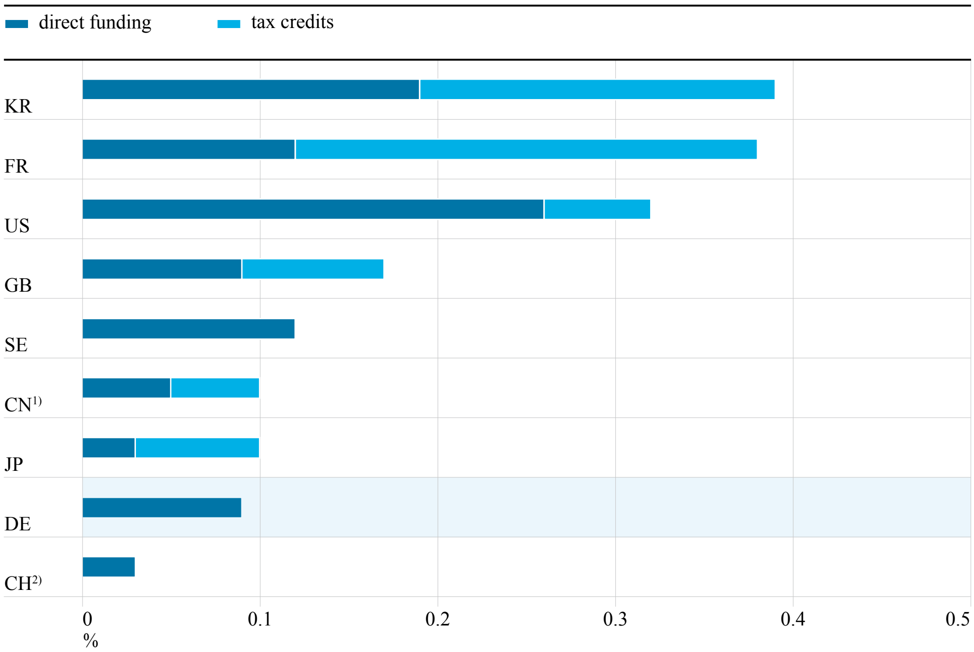
Figure C 4 – 2 provides an overview of the share of venture capital investment in national gross domestic product of selected countries. The figure shows that this share continues to be relatively low in Germany. In other European countries such as Sweden, Finland, Great Britain and Switzerland, venture capital investment relative to gross domestic product is significantly higher. The development of venture capital investment in Germany in recent years suggests that the situation has not improved. Ever since the severe slump in the crisis year of 2009, venture capital investment has not only stagnated, but even declined in 2012 (C 4 – 3).

C 4 – 1

Share of the business sector's R&D expenditure directly and indirectly funded by the public sector, as a share of GDP, 2011 (figures in percent)

In most of the countries, tax credits for R&D – in addition to direct R&D funding (i.e. project funding) – play an important role in the public financing of R&D in the business sector.

DATA DOWNLOAD



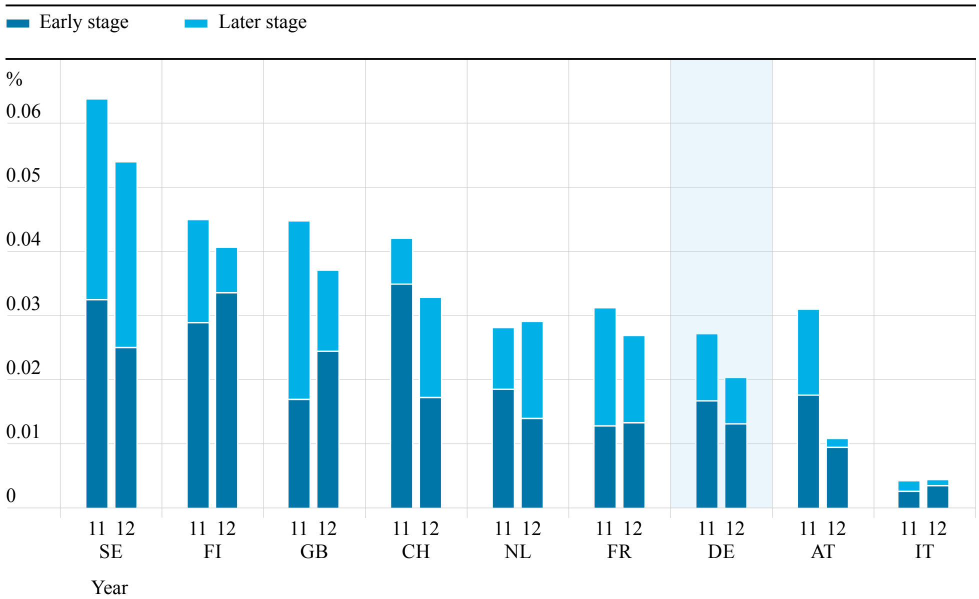
1) 2009; 2) 2008
Source: own depiction based on OECD Science, Technology and Industry Scoreboard 2013.

C 4 – 2

Venture capital investments as a share of national GDP
(investments according to registered office of the portfolio companies; figures in percent)

Between 2011 and 2012, the share of venture capital investments of national GDP has decreased in nearly all of the countries surveyed.

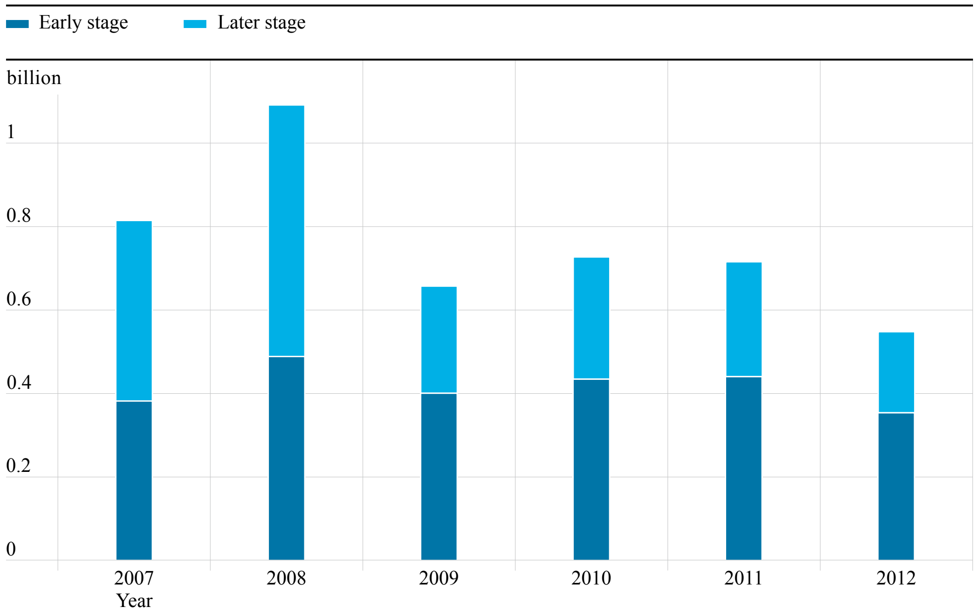
DATA DOWNLOAD



Early stage comprises the seed phase and the start-up phase.
Source: EVCA (2013), Eurostat. Own calculations.

C 4–3 **Development of venture capital investments in Germany**
(investments according to registered office of the portfolio companies)

DATA
DOWNLOAD



Early stage comprises the seed phase and the start-up phase.

The development of venture capital investments in Germany is stagnating at a low level.

NEW ENTERPRISES

C 5

The cost and burden of starting up a business (C 5 – 1) is measured on the basis of the World Bank's Doing Business data.[486] These include, inter alia, information on government regulations that affect the founding and the operation of businesses in 189 economies. More specifically, this includes the number of procedural steps required for registering a company, the number of days required for registration, the cost of registration, as well as the minimum capital requirements.[487] To facilitate the comparison between countries based on these indicators, a model enterprise profile has been created. Based on this model enterprise, the World Bank examines the government regulations that the model enterprise is subjected to.[488] In Germany, a relatively high number of procedural steps are required to start up a business. What is more, starting up a business is relatively time-consuming and expensive. Thus, Germany is ranked 111th among 189 countries, while major competitors such as the United States, Great Britain, Korea and France are ranked considerably higher.

An international comparison of start-up rates, i.e. the number of start-up businesses as a percentage of the total number of companies, can only be performed at a European level.[489] For this purpose, the Business Demography Statistics provided by Eurostat are used. These constitute part of the European Union's Structural Business Statistics (SBS).[490] With 12.8 percent in 2010, France recorded the highest start-up rate for all economic sectors from among the countries surveyed (cf. C 5 – 2). Germany had a start-up rate of 8.7 percent and was thus ranked well below France. With respect to start-ups in R&D intensive industries, Germany had a more favourable ranking. Here, the start-up rate amounted to 5.3 percent and was thus only slightly lower than that of Great Britain (5.6 percent), which displayed the highest value within the country sample. The start-up rate in France was relatively high in knowledge-intensive services (17.4 percent), while Germany (10.2 percent) remained far below this figure.

The findings on company dynamics in the knowledge economy as displayed in Figures C 5 – 3 to C 5 – 5 draw on an evaluation of the Mannheim Enterprise Panel (MUP) by the Centre for European Economic Research (ZEW).[491] The start-up rate shown in Figure C 5 – 3 is calculated on the basis of different data than those used in the Business Demography Statistics, which means that a direct comparison cannot be drawn here.[492] According to the data provided by the MUP, the start-up rate in the knowledge economy amounted to 5.8 percent in 2012 and thus declined for the fifth consecutive year (C 5 – 3). The closure rate in the knowledge economy, which amounted to 5.6 percent in 2012, also declined (C 5 – 4). The comparison at federal state level reveals significant differences in start-up rates in Germany (C 5 – 5). Across all industries, Germany's city states (i.e. Berlin, Bremen and Hamburg) record the highest rates here, with Berlin at the very top of the ranking. The East German federal states are lagging behind. The picture is more nuanced in R&D-intensive industries and knowledge-intensive services.

C 5–1 **Cost and burden of starting up a business**

DATA DOWNLOAD

	Number of procedural steps	Number of days required for completion of procedural steps	Cost of procedural steps (as a percentage of income per capita)	Minimum capital requirement (as a percentage of income per capita)	Ranking among 189 countries
US	6	5	1.5	0	20
GB	6	12	0.3	0	28
KR	5	5.5	14.6	0	34
FR	5	6.5	0.9	0	41
SE	3	16	0.5	13.1	61
CH	6	18	2	25.6	104
DE	9	14.5	4.7	0	111
JP	8	22	7.5	0	120
CN	13	33	2	78.2	158

Source: Doing Business (World Bank).

Number of procedural steps: the number of procedural steps required for registering a business. Procedural steps refer to any type of interaction between entrepreneurs and external stakeholders or institutions (e.g. state, agencies, solicitors).

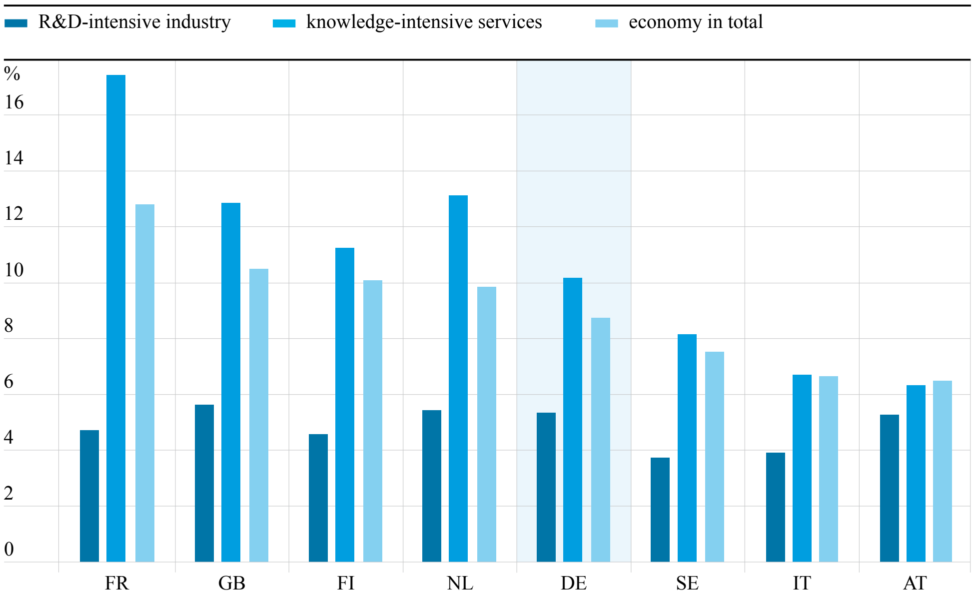
Number of days required for procedural steps: total number of days required for registering a business.

Cost of procedural steps: cost include public fees and fees for services prescribed by law.

Minimum capital requirement: funds the entrepreneur is required to deposit in the bank or with a notary before registration and up to three months following registration.

C 5–2 **Start-up rates in 2010 in international comparison** (figures in percent)

DATA DOWNLOAD



Source: Business Demography Statistics (Eurostat). Calculations by ZEW.

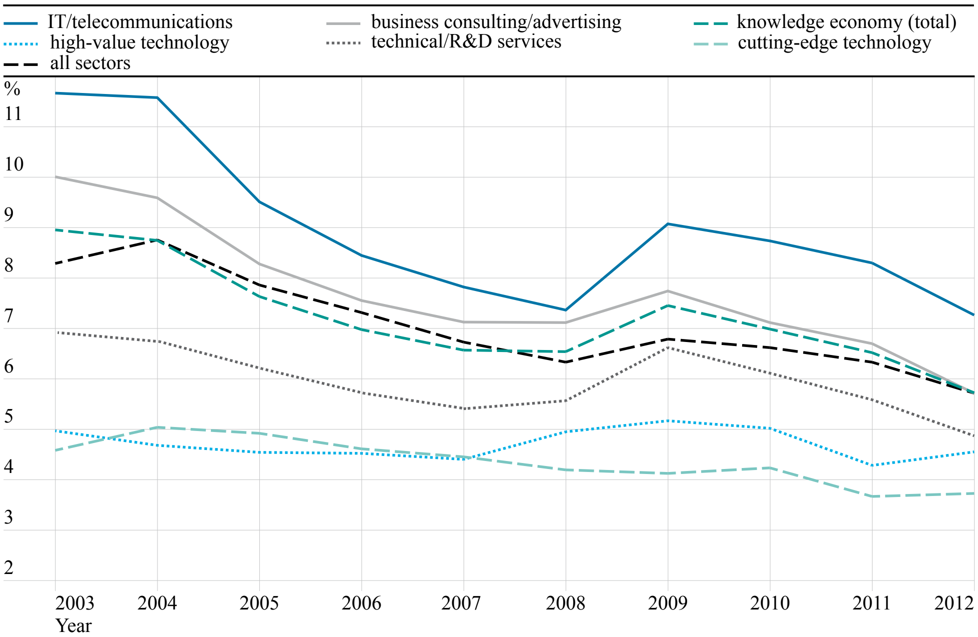
Start-up rate: number of start-up businesses as a percentage of total number of companies.

Start-up rates in Germany's knowledge economy (figures in percent)

C 5–3

DATA DOWNLOAD

Start-up rate: number of start-up businesses as a percentage of total number of companies.



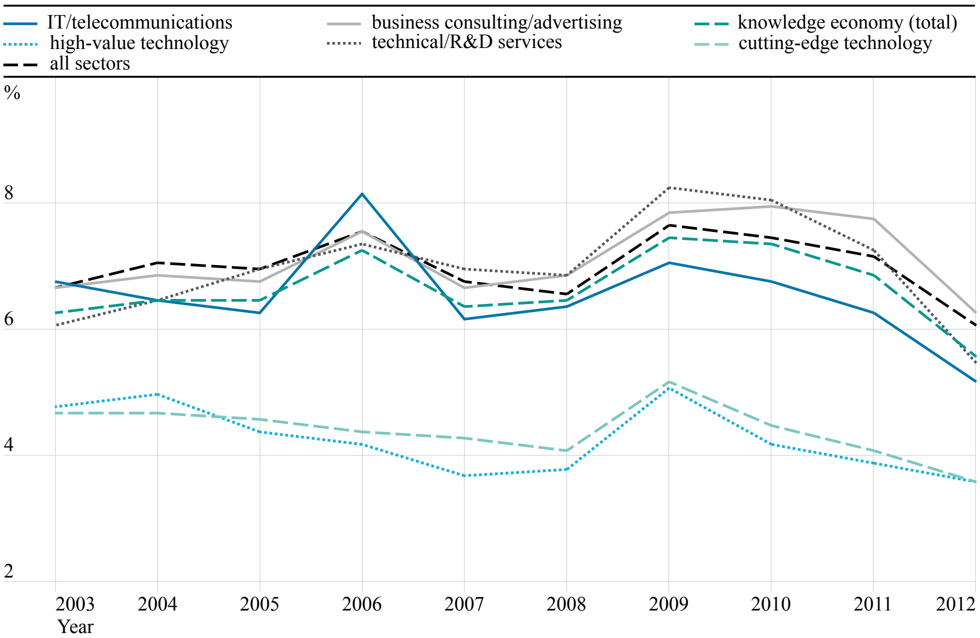
All figures are provisional.
Source: Mannheim Enterprise Panel (ZEW). Calculations by ZEW.

Closure rates in Germany's knowledge economy (figures in percent)

C 5–4

DATA DOWNLOAD

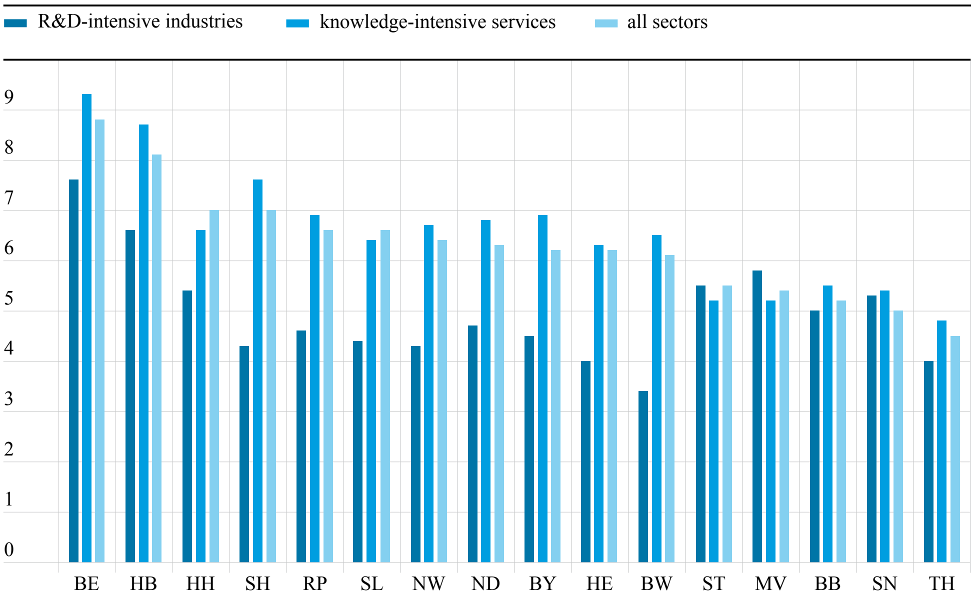
Closure rate: number of companies shut down during the course of a year, as a percentage of total number of companies.



All figures are provisional.
Source: Mannheim Enterprise Panel (ZEW). Calculations by ZEW.

C 5–5 **Start-up rates according to federal states 2010 – 2012** (figures in percent)

DATA DOWNLOAD



All figures are provisional.
Source: Mannheim Enterprise Panel (ZEW). Calculations by ZEW.

Start-up rate: number of start-up businesses as a percentage of total number of companies.

PATENTS C 6

In 2011, most of the countries managed to recover further from the international financial and economic crisis. In terms of transnational patent applications, the United States did not regain the maximum value recorded in 2006 (cf. C 6 – 1). Yet, a slight increase in US patent applications can be observed for the period 2010 to 2012. Judging by the number of patents filed, Japan in particularly managed to swiftly catch up with the values recorded prior to the crisis. Although Germany recorded but a slight increase, it continues to be one of the world's leading countries in transnational patent applications, just after the United States and Japan.

Ever since the late 1990s, China and Korea have been recording the highest growth rates, leaving countries such as France and Great Britain behind. Sweden and Switzerland follow at a somewhat greater distance behind Great Britain.

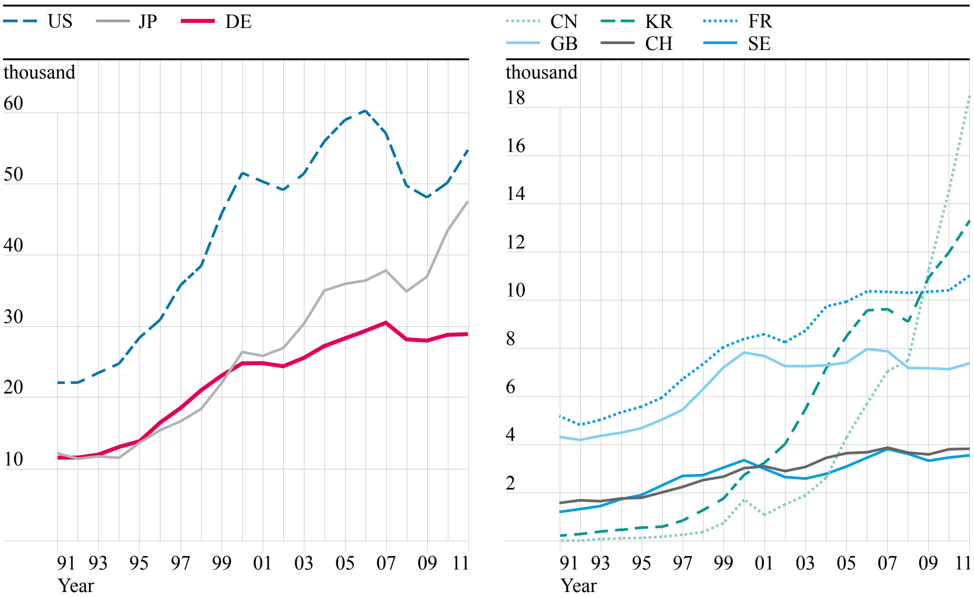
While the United States are leading in terms of the absolute number of patent applications, they do not maintain a leading position with regard to patent intensity (patent applications per 1 million of the working population). The US are ranked in the middle field, together with such countries as France and Great Britain (cf. C 6 – 2), while the top positions are occupied by smaller countries such as Switzerland and Sweden. The larger countries ranked in the upper third are Japan, Germany and Korea. Patents are an important tool to secure market shares in international trade in technology.[493] A high patent intensity therefore reflects both a strong international orientation and a pronounced export focus of the relevant economy.

Further conclusions on a country's technological performance can be derived from patent activities in the field of high technology. This sector includes industries that invest more than 2.5 percent of their revenue in R&D (R&D intensity). High technology comprises the area of high-value technology (R&D intensity between 2.5 and 9 percent) and the area of cutting-edge technology (R&D intensity > 9 percent). The patent statistics for Germany show a strong specialisation in high-value technology (cf. C 6 – 3). Thanks to the automotive, mechanical engineering and chemical industry, the production of high-value technology represents a traditional domain of German industry. Japan is the only country that displays a higher degree of specialisation than Germany.

In contrast, China, Korea and the United States display a strong focus on cutting-edge technologies. Germany continues to be poorly positioned in this area and remains far behind Japan and the European countries of France and Great Britain (C 6 – 4).

C 6–1 **Development of numbers in transnational patent applications over time for selected countries**

DATA DOWNLOAD



Source: EPA (PATSTAT), calculations by Fraunhofer ISI. December 2013.

Transnational patent applications comprise applications in the form of patent families that include at least one application filed with the World Intellectual Property Organization (WIPO), via the Patent Cooperation Treaty (PCT) procedure, or an application filed with the European Patent Office.

C 6–2 **Transnational patent applications in the field of high technology: absolute number, intensity and growth rates in 2011**

DATA DOWNLOAD

	absolute	intensity	intensity high technology	total growth in % (2001 = 100)	growth in high technology in % (2001 = 100)
Total	**228,142**	**–**	**–**	**144**	**151**
CH	3,834	878	470	123	122
FI	1,929	780	481	106	94
SE	3,560	769	522	119	127
JP	47,683	758	492	184	188
DE	29,035	731	412	116	113
KR	13,312	549	367	409	440
NL	3,924	469	245	95	79
FR	11,028	428	253	128	136
US	54,887	392	259	109	111
EU-28	72,965	334	190	120	119
GB	7,384	254	151	96	98
IT	5,275	230	117	121	128
CA	3,643	210	137	133	134
CN	18,496	24	17	1,701	2,098

Source: EPA (PATSTAT). OECD (MSTI). Calculations by Fraunhofer ISI. December 2013.

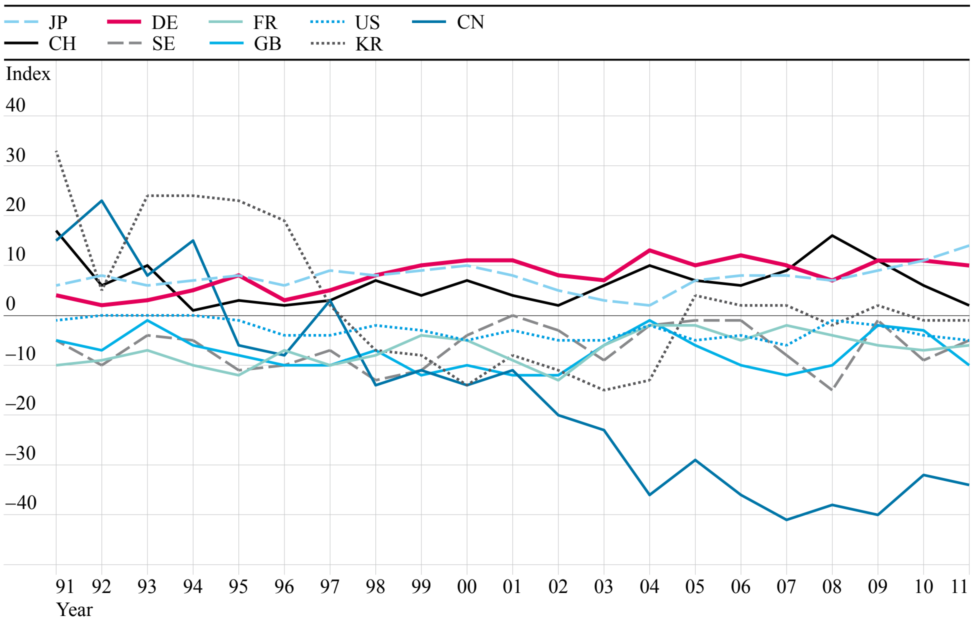
The high technology industry sector comprises industries that invest more than 2.5 percent of their revenue in research and development. “Intensity” refers to the number of patents per one million gainfully employed persons.

Development of the high-value technology specialisation index over time, for selected countries

C 6–3

DATA DOWNLOAD

The specialisation index is calculated on the basis of all transnational patent applications worldwide. Positive or negative values indicate if the surveyed country's level of activity in a given field is disproportionately high or disproportionately low in comparison to the global average.



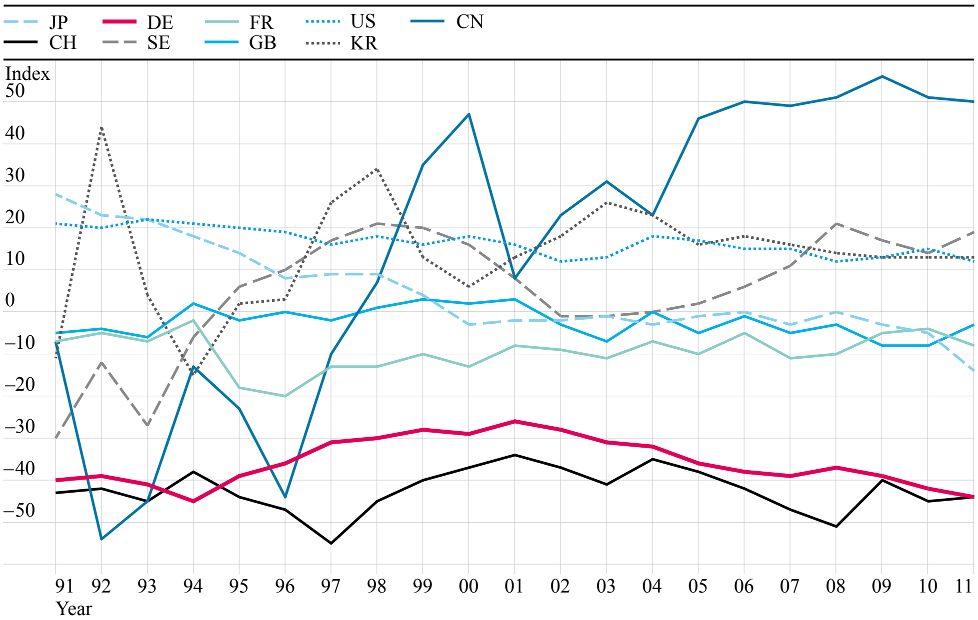
Source: Questel (EPPATENT, WOPATENT). EPA (PATSTAT). Calculations by Fraunhofer ISI. December 2013.

Development of the cutting-edge technology specialisation index over time, for selected countries

C 6–4

DATA DOWNLOAD

The specialisation index is calculated on the basis of all transnational patent applications worldwide. Positive or negative values indicate if the surveyed country's level of activity in a given field is disproportionately high or disproportionately low in comparison to the global average.



Source: Questel (EPPATENT, WOPATENT). EPA (PATSTAT). Calculations by Fraunhofer ISI. December 2013.

C 7 SCIENTIFIC PUBLICATIONS

The bibliometric database Web of Science (WoS) records publications in scientific journals as well as citations of these publications on a global scale. The research affiliation of a scientist referenced in the database makes it possible to assign individual level publications to a specific country. In cases where co-authors of a single publication reside in different countries, fractional counting is employed.

National shares in all Web of Science publications changed significantly between 2002 and 2012 (cf. C 7–1). China in particular managed to almost triple its share from 3.9 to 11.6 percent. But also the shares of Korea, Brazil and India have increased considerably over the past decade. In contrast, the shares of established science systems such as those of the United States, Japan, Great Britain and Germany decreased: the US lost nearly 6 percentage points, and Germany just over 1 percentage point. Despite the massive growth in publications in Asia and the BRICS countries, some countries still succeeded in keeping their share constant over time. Notably, these countries include e.g. Canada, the Netherlands, Denmark and Italy.

In 2010, scientists in Switzerland, the Netherlands, Denmark and the United States succeeded in placing their publications particularly in scientific journals with an international audience (cf. C 7–2). Germany is currently at a level comparable to that of Great Britain. With respect to this excellence and quality indicator, positive dynamics can be observed in the Netherlands, Denmark, Israel, Belgium and Germany. Compared with this, scientists in the United States seem to be losing ground not only with regard to the quantity (see above), but also with regard to the quality of their published works. Many of the BRICS countries (Russia and Brazil excluded) succeeded in improving their global position in the index over time.

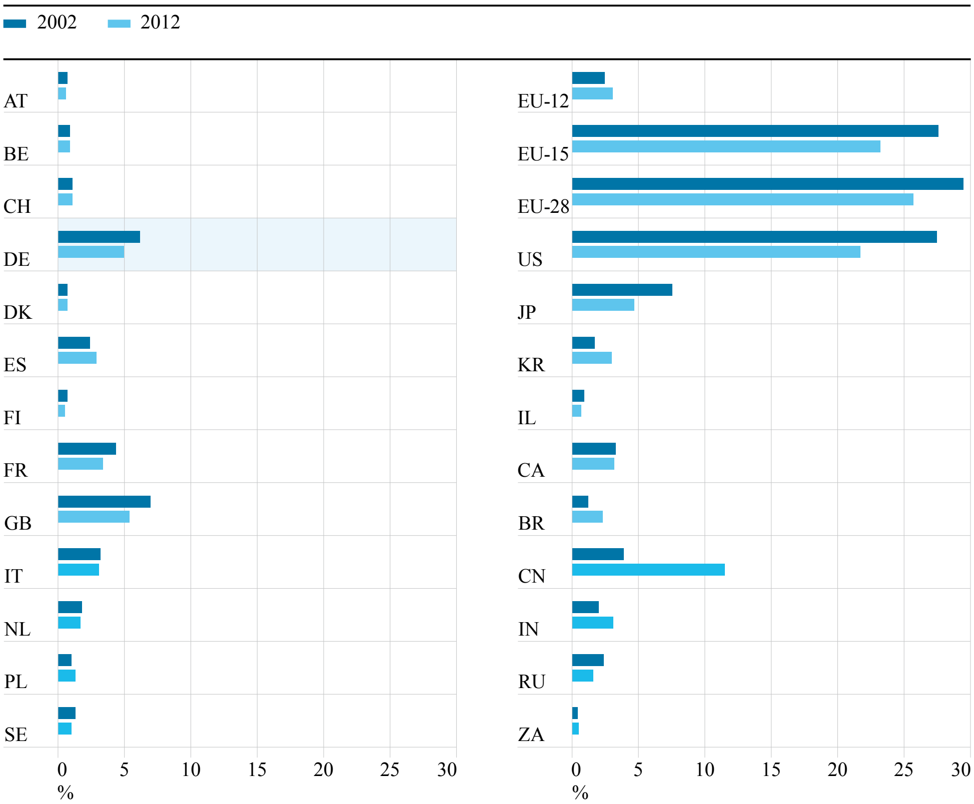
When compared internationally, publications from China, Denmark and Switzerland are most frequently cited in scientific journals (C 7–3) and are thus more frequently cited than publications from the United States or Great Britain. Denmark, China and the Netherlands experienced a particularly promising development in the last decade, while a decline could be observed mainly in the United States, Great Britain and Switzerland. Also with regard to this indicator, scientists from individual BRICS countries managed to catch up considerably. Germany's position, however, deteriorated significantly. With regard to the two quality indicators for publication activities of scientists in Germany, the overall picture emerging from this is thus mixed. (C 7–2 and C 7–3).

C 7–1

Shares of selected countries and regions for Web of Science publications in 2002 and 2012 (figures in percent)

DATA DOWNLOAD

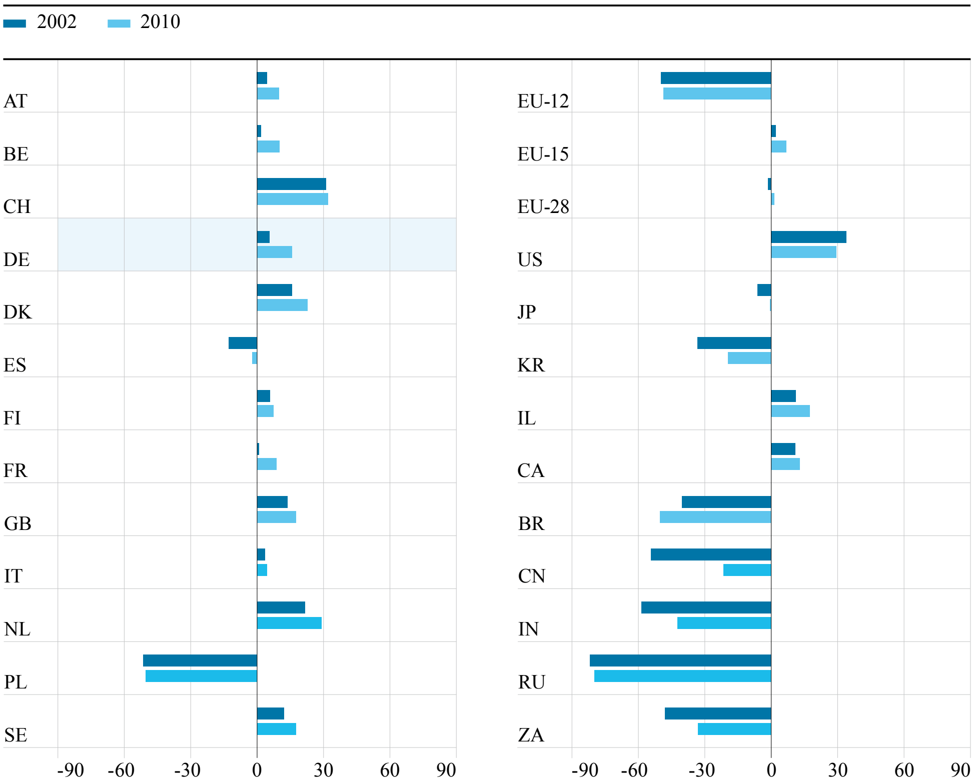
In order to take account for changes in the collection of publication data – continuous expansion in particular – countries' shares of publications, and not absolute numbers of publications, are considered here.



Source: Web of Science. Research and calculations by Fraunhofer ISI. Fractional counting method.

C 7–2 **International alignment of selected countries and regions for Web of Science publications in 2002 and 2010** (index values)

DATA DOWNLOAD



Source: Web of Science. Research and calculations by Fraunhofer ISI. Fractional counting method.

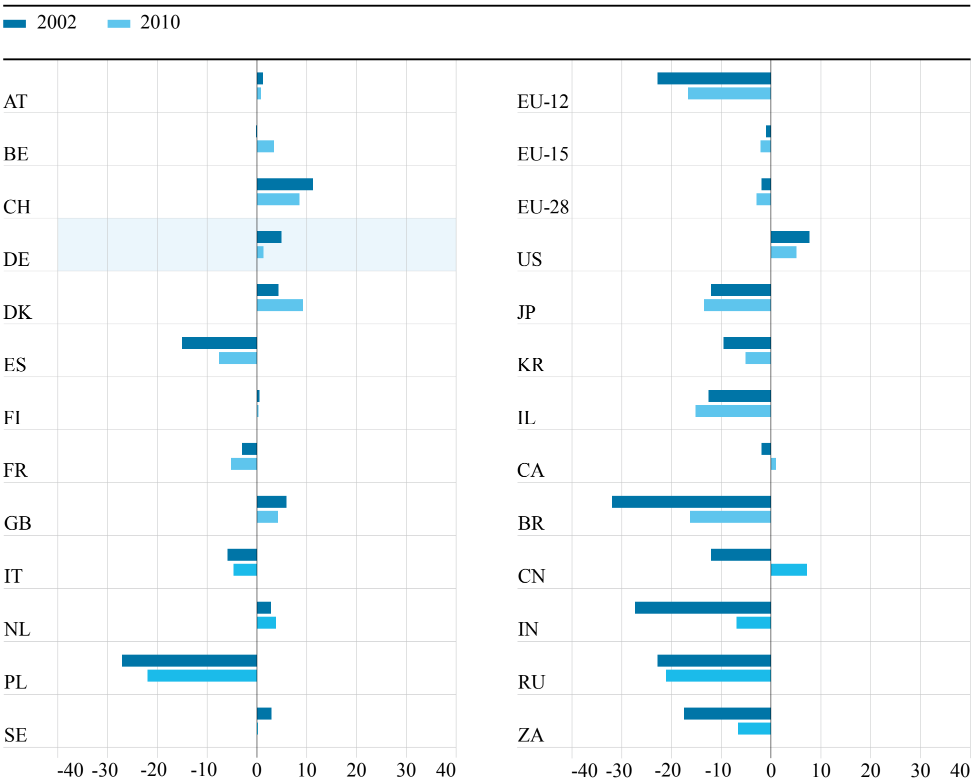
The international alignment (IA) index shows the extent to which a country's authors, in comparison to the world average, are publishing in internationally renowned journals and less-renowned journals. Positive values are indicative of above-average IA; negative values are indicative of below-average IA.

Scientific regard for Web of Science publications from selected countries and regions in 2002 and 2010 (index values)

C 7–3

DATA DOWNLOAD

The scientific regard (SR) index shows whether a country's scientific articles are, on average, cited more or less frequently than other articles published in the same journals. Positive values are indicative of above-average SR; negative values are indicative of below-average SR. Index calculations do not include self-citations.



Source: Web of Science. Research and calculations by Fraunhofer ISI. Fractional counting method.

C 8 PRODUCTION, VALUE ADDED AND EMPLOYMENT

As in previous years, Germany showed a comparative advantage in trade in R&D-intensive goods in 2012.[494] A country's comparative advantage is determined by the RCA indicator, which measures a product group's export/import ratio relative to the export/import ratio of the manufacturing sector as a whole. A closer analysis reveals, however, that Germany has a positive comparative advantage only in terms of trade in high-value technology; trade in cutting-edge technology displays a negative comparative advantage. Further countries with a negative RCA indicator in the area of cutting-edge technology in 2012 were Sweden, Japan and China. Positive values were recorded in France, Great Britain, Switzerland, the United States and Korea (C 8 – 1).

The share of research and knowledge-intensive industries in a country's value added reflects their importance and allows conclusions to be drawn on the country's technological performance. Overall, this share increased in nearly all the surveyed countries between 2000 and 2011 (C 8 – 2), which suggests a growing relevance of research and knowledge-intensive industries. In most of the countries, the increase was mainly attributable to knowledge-intensive services. Only Switzerland, Germany and Korea recorded an increase in the share of R&D-intensive industries in value added.

While the gross value added had experienced a decline in various industrial sectors during the crisis year of 2009, value added in Germany increased again in 2010 and 2011 and even exceeded the levels recorded prior to the crisis (C 8 – 3). Between 2010 and 2011, the highest increase in added value could be observed in the knowledge-intensive manufacturing sector (4.9 percent) and in the non-knowledge-intensive manufacturing sector (7.4 percent).

A similar trend could be observed in the development of employment covered by social security (C 8 – 4). Following a slight decline in 2009, the number of employees increased from 2010. Between 2010 and 2011, employment in knowledge-intensive services and in the knowledge-intensive manufacturing sector recorded the highest increase, with 3.1 percent and 2.7 percent respectively.

Comparative advantages (Revealed Comparative Advantage, RCA) of selected countries in foreign trade in research-intensive goods

C 8–1

DATA DOWNLOAD

A positive RCA value means that the export-import relation for this product group is higher than it is for manufactured industrial goods as a whole.

Year	DE	FR	GB	SE	CH	US[1]	JP	KR	CN[2]
R&D-intensive goods									
2000	11	7	14	0	10	13	47	0	–41
2005	10	7	14	–1	18	17	42	17	–29
2010	12	6	11	–6	22	1	33	19	–27
2011	15	5	9	–5	22	–1	36	15	–27
2012	15	7	10	–11	21	–2	35	17	–28
High-value technology									
2000	27	5	10	–7	26	–13	86	5	–17
2005	27	6	4	–2	24	–5	75	11	0
2010	30	–2	15	–3	21	–10	61	7	–16
2011	31	–4	11	–3	19	–9	64	13	–20
2012	29	–3	13	–6	17	–12	68	16	–13
Cutting-edge technology									
2000	–27	11	19	13	–30	47	–10	–5	–66
2005	–34	8	33	1	4	55	–14	24	–53
2010	–35	20	1	–11	25	22	–22	33	–35
2011	–30	20	6	–9	29	12	–21	18	–33
2012	–23	21	2	–25	31	15	–29	18	–41

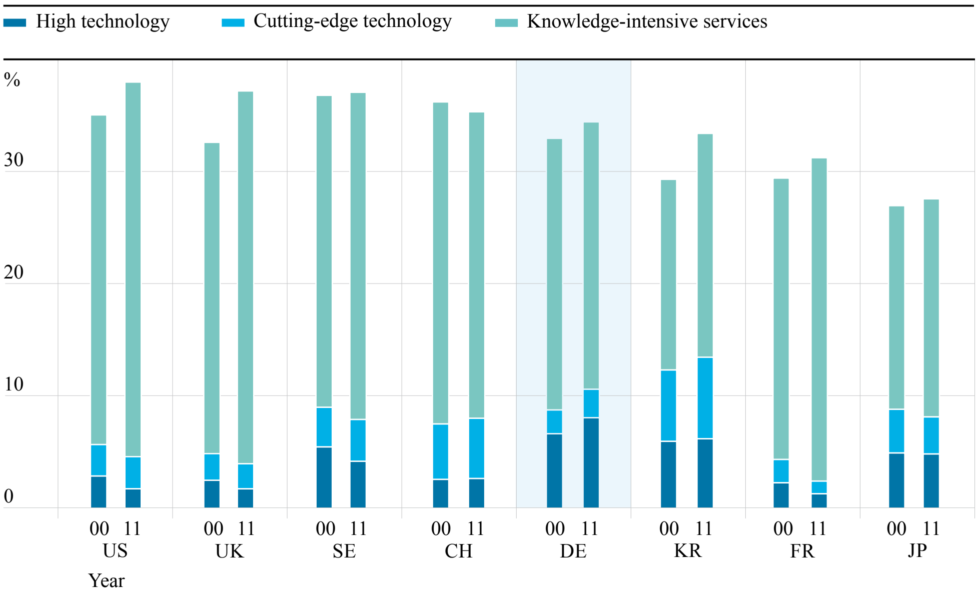
[1] Figures for the USA revised from 2009 based on national data. [2] incl. Hong Kong.
Source: COMTRADE database. Calculations and estimates by NIW.

Shares of R&D-intensive industries and knowledge-intensive services in value added (figures in percent)

C 8–2

DATA DOWNLOAD

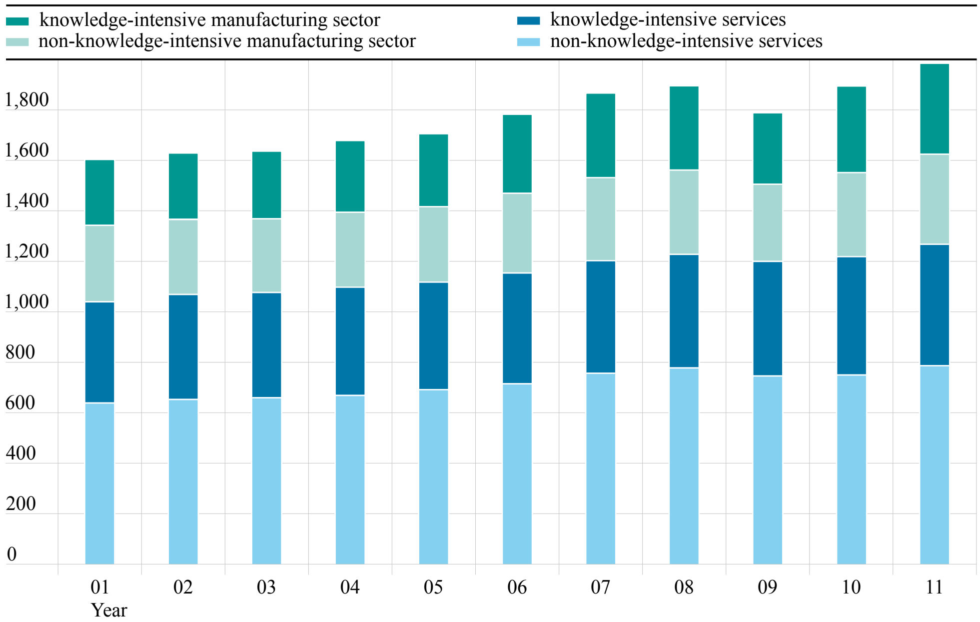
The share of R&D intensive industries and knowledge-intensive services in value added has increased over the last decade in nearly all of the countries surveyed.



Source: OECD STAN (2013), Eurostat (2013), EUKLEMS (2013, 2007), BEA (2013), BOK (2013), Statistics Bureau - Ministry of Internal Affairs and Communications Japan (2013). Calculations and estimates by DIW Berlin.

C 8–3 **Development of gross value added in various industry sectors in Germany**
(in billion EUR)

DATA DOWNLOAD

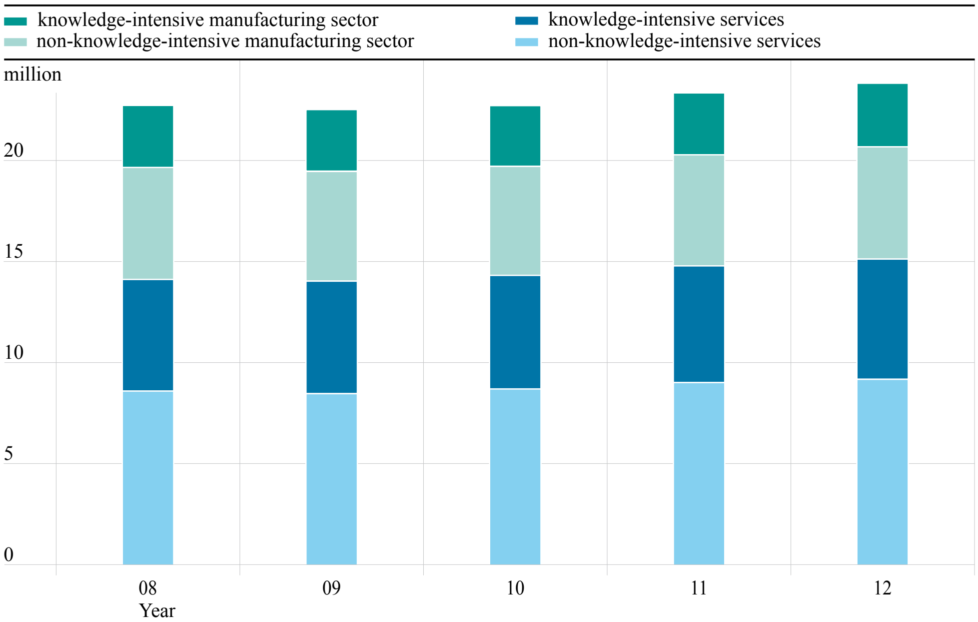


Not including agriculture and forestry, fisheries, public administration and services, real estate and housing, education, private households, etc.
Source: *Statistisches Bundesamt, Fachserie 18, Reihe 1.4.* Calculations by NIW.

Between 2001 and 2011, gross value added in the knowledge-intensive and non-knowledge-intensive manufacturing sector increased by 37.6 and 18.0 percent, respectively. In knowledge-intensive and non-knowledge-intensive services it increased by 19.9 and 23.1 percent, respectively.

C 8–4 **Employment trends in various industry sectors in Germany**

DATA DOWNLOAD



Source: *Bundesagentur für Arbeit.* Calculations by NIW.

Between 2008 and 2012, employment in the knowledge-intensive and non-knowledge-intensive manufacturing sector increased by 2.1 and 0.2 percent, respectively. In knowledge-intensive and non-knowledge-intensive services, it increased by 7.7 and 6.7 percent, respectively.

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D REFERENCES

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LIST OF ABBREVIATIONS

ACHSE	*Allianz Chronischer Seltener Erkrankungen* (Alliance of Chronic Rare Diseases)
AHSC	Academic Health Science Centres
approx.	approximately
Art.	Article
AufenthG	*Aufenthaltsgesetz* (German Residence Act)
BAMF	*Bundesamt für Migration und Flüchtlinge* (Federal Office for Migration and Refugees)
BD2K	Big Data to Knowledge
BEA	Bureau of Economic Analysis
BIG	*Berliner Institut für Gesundheitsforschung* (Berlin Institute of Health)
BIT	Behavioural Insights Team
BITKOM	*Bundesverband Informationswirtschaft, Telekommunikation und neue Medien e.V.* (Federal Association for Information Technology, Telecommunications and New Media)
BMBF	*Bundesministerium für Bildung und Forschung* (Federal Ministry of Education and Research)
BMFSFJ	*Bundesministerium für Familie, Senioren, Frauen und Jugend* (Federal Ministry of Family Affairs, Senior Citizens, Women and Youth)
BMG	*Bundesministerium für Gesundheit* (Federal Ministry of Health)
BMU	*Bundesministerium für Umwelt Naturschutz und Reaktorsicherheit / Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit* (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety / Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety)
BMVBS	*Bundesministerium für Verkehr, Bau und Stadtentwicklung* (Federal Ministry of Transport, Building and Urban Development)
BMWi	*Bundesministerium für Wirtschaft und Technologie / Bundesministerium für Wirtschaft und Energie* (Federal Ministry of Economics and Technology / Federal Ministry for Economic Affairs and Energy)
BOK	Bank of Korea
BRIC	Brazil, Russia, India and China
BRICS	Brazil, Russia, India, China and South Africa
ca.	circa
CAS	Certificate of Advanced Studies
CDU	*Christlich Demokratische Union Deutschlands* (Christian Democratic Union of Germany)
CEO	Chief Executive Officer
cf.	confer
CfE	Center for Excellence
CHIR-Net	*Studiennetzwerk Chirurgie* (Study Network Surgery)
CIHR	Canadian Institutes of Health Research
CIS	Community Innovation Survey
CNC	Computer Numerical Control
CNW	*Curricularnormwert* (curricular standard)
COMTRADE	Commodity Trade Statistics
CPB	Centraal Planbureau

CSU	*Christlich-Soziale Union* (Christian Social Union in Bavaria)
D.C.	District of Columbia
DAAD	*Deutscher Akademischer Austauschdienst e.V.* (German Academic Exchange Service)
DAX	*Deutscher Aktienindex* (German stock index)
DFG	*Deutsche Forschungsgemeinschaft e.V.* (German Research Foundation)
DGFP	*Deutsche Gesellschaft für Personalführung mbH* (German Association for People Management)
DGIM	*Deutsche Gesellschaft für Innere Medizin e.V.* (German Society of Internal Medicine)
DICE	Düsseldorf Institute for Competition Economics
DIW	*Deutsches Institut für Wirtschaftsforschung e.V.* (German Institute for Economic Research)
DLR	*Deutsches Zentrum für Luft- und Raumfahrt e.V.* (German Aerospace Center)
DRG	Diagnosis Related Groups
DRKS	*Deutsches Register Klinischer Studien* (German Clinical Trials Register)
DZG	*Deutsche Zentren der Gesundheitsforschung* (German Centres for Health Research)
e.g.	*exempli gratia* (for example)
e.V.	*eingetragener Verein* (registered association)
EEA	European Economic Area
EEG	*Erneuerbare-Energien-Gesetz* (Renewable Energy Sources Act)
EFI	*Expertenkommission Forschung und Innovation* (Commission of Experts for Research and Innovation)
EITO	European Information Technology Observatory
EP PATENT	European Patent Database
EPO	European Patent Office
ERA	European Research Area
ERC	European Research Council
et al.	*et alii* (and others)
etc.	et cetera
ETSI	European Telecommunications Standards Institute
EU	European Union
EU ETS	European Union Emissions Trading System
EU KLEMS	EU Level Analysis of Capital, Labour, Energy, Materials and Service Inputs
EUROSTAT	Statistical Office of the European Commission
EVCA	European Private Equity & Venture Capital Association
f.	following
ff.	and the following
FH	*Fachhochschule* (university of applied sciences)
Fig.	Figure
FRAND	fair, reasonable and non-discriminatory
GAIN	German Academic International Network
GBAORD	Government Budget Appropriations or Outlays for Research and Development
GDP	Gross Domestic Product
GDR	German Democratic Republic
GG	*Grundgesetz* (German Basic Law)
GKV	*Gesetzliche Krankenversicherung* (statutory health insurance)
GPT	General Purpose Technology
GSM	Global System for Mobile Communications
GWK	*Gemeinsame Wissenschaftskonferenz* (Joint Science Conference)
HGF	*Helmholtz-Gemeinschaft Deutscher Forschungszentren* (Helmholtz Association)

HIS	*Hochschul-Informations-System* (Higher Education Information System)
HTS	High-Tech Strategy
HWK	*Handwerkskammer* (Chamber of Crafts)
I&C	information & communication
i.e.	id est (that is)
I2b2	Informatics for Integrating Biology and the Bedside
IAB	*Institut für Arbeitsmarkt- und Berufsforschung* (Institute for Employment Research)
ICT	information and communication technologies
IFB	*Integrierte Forschungs- und Behandlungszentren* (Integrated Research and Treatment Centers)
IGES	*Institut für Gesundheits- und Sozialforschung GmbH*
InEK	*Institut für das Entgeltsystem im Krankenhaus GmbH*
IP	intellectual property
IQ	intelligence quotient
ISCED	International Standard Classification of Education
ISI	*Institut für System- und Innovationsforschung* (Institute for Systems and Innovation Research)
ISO	International Organization for Standardization
IT	information technology
ITU	International Telecommunication Union
KapVO	*Kapazitätsverordnung* (capacity regulations)
KKS	*Koordinationszentrum für Klinische Studien* (Coordinating Centre for Clinical Trials)
KMK	*Kultusministerkonferenz* (The Standing Conference of the Ministers of Education and Cultural Affairs of the *Länder*)
LMU	*Ludwig-Maximilians-Universität München* (Ludwig Maximilians University of Munich)
LTE	Long Term Evolution
MAS	Master of Advanced Studies
MBA	Master of Business Administration
MD	Doctor of Medicine
MDAX	Mid-Cap DAX
MDC	*Max-Delbrück-Centrum für Molekulare Medizin* (Max Delbrück Center for Molecular Medicine)
MFT	*Medizinischer Fakultätentag der Bundesrepublik Deutschland e.V.* (German Medical Faculty Association)
MIP	*Mannheimer Innovationspanel* (Mannheim Innovation Panel)
MIT	Massachusetts Institute of Technology
MNC	multinational corporations
MUP	*Mannheimer Unternehmenspanel* (Mannheim Enterprise Panel)
NCBC	National Center for Biomedical Computing
NCRR	National Center for Research Resources
NIH	National Institutes of Health
NIH CC	National Institutes of Health Clinical Center
NIP	*Nationales Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie* (National Innovation Programme for Hydrogen and Fuel Cell Technology)
NIW	*Niedersächsisches Institut für Wirtschaftsforschung e.V.* (Lower Saxony Institute for Economic Research)
No.	Number
NOW	*Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie* (National Organisation Hydrogen and Fuel Cell Technology)

NWO	Nederlandse Organisatie voor Wetenschappelijk Onderzoek
OECD	Organisation for Economic Co-operation and Development
OMB	Office of Management and Budget
p.a.	per annum
PAED-Net	*Pädiatrisches Netzwerk zur Arzneimittelentwicklung und -prüfung bei Kindern und Jugendlichen* (Pediatric Network on Medication Development and Testing in Children and Adolescents)
PATSTAT	EPO Worldwide Patent Statistical Database
PC	personal computer
PCT	Patent Cooperation Treaty
PhD	Doctor of Philosophy
PISA	Programme for International Student Assessment
R&D	Research and Development
R&I	Research and Innovation
RCA	Revealed Comparative Advantage
RD	rare diseases
RIS3	Regional Research and Innovation Strategies for Smart Specialisation
RNA	ribonucleic acid
RPDR	Research Patient Data Repository
RWTH	*Rheinisch-Westfälische Technische Hochschule* (Aachen University of Technology)
SDAX	Small-Cap DAX
SDGC	*Studienzentrum der Deutschen Gesellschaft für Chirurgie* (Study Centre of the German Surgical Society)
SEP	standard-essential patents
SGB	*Sozialgesetzbuch* (German Social Code)
SHRINE	Shared Health Research Information Network
SIGNO	*Schutz von Ideen für die Gewerbliche Nutzung* (Protection of Ideas for Commercial Use)
SME	small and medium-sized enterprises
SNIP	Source-Normalized Impact per Paper
SPD	*Sozialdemokratische Partei Deutschlands* (Social Democratic Party of Germany)
SRDC	Social Research and Demonstration Corporation
STAN	Structural Analysis Database
STEM	Science, Technology, Engineering, Mathematics
SUS	*Strukturelle Unternehmensstatistik* (structural business statistics)
Tab.	Table
TecDAX	Stock index that includes the 30 largest technology companies in Germany
TMF	*Technologie- und Methodenplattform für die vernetzte medizinische Forschung e.V.* (Technology, Methods, and Infrastructure for Networked Medical Research)
TU	*Technische Universität* (technical university)
TÜV	*Technischer Überwachungsverein* (Technical Inspection Agency)
UMC	Universitair Medisch Centrum
UMTS	Universal Mobile Telecommunications System
US	United States
USA	United States of America
VCI	*Verband der Chemischen Industrie e.V.* (German Chemical Industry Association)
VDA	*Verband der Automobilindustrie e.V.* (German Association of the Automotive Industry)
VDMA	*Verband Deutscher Maschinen- und Anlagenbau e.V.* (German Engineering Association)
vfa	*Verband Forschender Arzneimittelhersteller e.V.* (Association of Research-Based Pharmaceutical Companies)
VUD	*Verband der Universitätsklinika Deutschlands e.V.* (Association of University Hospitals in Germany)

wbv	*W. Bertelsmann Verlag*
WIPO	World Intellectual Property Organization
WO PATENT	World Intellectual Property Organization Database
WoS	Web of Science
WWC	WhatWorksClearinghouse
ZEW	*Zentrum für Europäische Wirtschaftsforschung GmbH* (Centre for European Economic Research)
ZVEI	*Zentralverband Elektrotechnik- und Elektronikindustrie e.V.* (German Electrical and Electronic Manufacturers' Association)

LIST OF ABBREVIATIONS OF NAMES OF COUNTRIES

AT	Austria
AU	Australia
BE	Belgium
BG	Bulgaria
BR	Brazil
CA	Canada
CH	Switzerland
CN	China
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GB	Great Britain
GR	Greece
HU	Hungary
IE	Ireland
IL	Israel
IN	India
IS	Iceland
IT	Italy
JP	Japan
KR	Korea
LU	Luxembourg
LT	Lithuania
LV	Latvia
NL	Netherlands
NO	Norway
PL	Poland
PT	Portugal
RO	Romania
RU	Russia
SE	Sweden
SI	Slovenia
SK	Slovakia
TW	Taiwan
US	United States of America
ZA	South Africa

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

LIST OF DEFINITION BOXES

CLASSIFICATION OF ECONOMIC ACTIVITIES FOR R&D-INTENSIVE INDUSTRY AND KNOWLEDGE-INTENSIVE INDUSTRY SERVICES

EXPLANATORY NOTES ON THE REDESIGN OF THE LIST OF RESEARCH-INTENSIVE ECONOMIC ACTIVITIES

The switch-over from the WZ 2003 classification scheme to the WZ 2008 classification scheme involved a redesign of the list of research-intensive industries.[495] The newly established threshold for defining research-intensive industries is based on the OECD countries' sectoral R&D intensity at the two-digit level of economic activity for the years 2008 and 2009. For the years 2007 and 2009, the German economy is analysed in more depth based on three and four-digit levels of activity. Economic activities are considered research-intensive if their R&D intensity lies above the average R&D intensity of the manufacturing industry as a whole.

For the manufacturing industry as a whole, the average R&D intensity across all OECD countries (i.e. internal R&D spending relative to the sectoral production value) for the years 2008 and 2009 amounted to 2.7 percent. This value has been rounded to 3 percent and has been defined as the threshold value.[496] Economic activities with an R&D intensity above this threshold are defined as research-intensive.

According to the new definition, the chemical industry and the manufacture of electrical equipment are no longer considered research-intensive industries. R&D intensity has significantly declined in the chemical industry over the last decade. While the chemical industry still achieved an above-average R&D intensity in the 1990s, it achieved only average values in 2003.[497] The switch-over to the new classification scheme for economic activities has had a major impact on the manufacture of electrical equipment: according to the new classification, e.g. the highly R&D-intensive manufacture of electronic equipment for motor vehicles is now assigned to automotive engineering, while it was previously assigned to electrical equipment.

Research-intensive industries continue to be subdivided into high-value technology and cutting-edge technology. This distinction is again based on the R&D intensity of economic activities. Here it could be shown that economic activities are concentrated at intensity values of slightly above 3 percent and between 9 and 15 percent, with a significant gap between these values.[498] Based on this, the following thresholds have been defined: economic activities with an R&D intensity between 3 percent and 9 percent are assigned to high-value technology, and industries with an R&D intensity above 9 percent are assigned to cutting-edge technology.

Since data on R&D expenditure for Germany are available at the four-digit level of economic activity, the list of research-intensive industries derived from this can also be presented at the four-digit level.[499] According to the four-digit classification of economic activities list, those sub-sectors of the chemical industry and the manufacture of electrical equipment that have a higher R&D intensity than the industry as a whole have also been assigned to the research-intensive industries group.

R&D-INTENSIVE INDUSTRIAL SECTORS WITHIN THE CLASSIFICATION OF ECONOMIC ACTIVITIES, 2008 EDITION (WZ 2008) (4-DIGIT CLASSES)

WZ 2008	**Cutting-edge technology**
20.20	Manufacture of pesticides and other agrochemical products
21.10	Manufacture of basic pharmaceutical products
21.20	Manufacture of pharmaceutical preparations
25.40	Manufacture of weapons and ammunition
26.11	Manufacture of electronic components
26.20	Manufacture of computers and peripheral equipment
26.30	Manufacture of communication equipment
26.51	Manufacture of instruments and appliances for measuring, testing and navigation
26.60	Manufacture of irradiation, electromedical and electrotherapeutic equipment
26.70	Manufacture of optical instruments and photographic equipment
29.31	Manufacture of electrical and electronic equipment for motor vehicles
30.30	Manufacture of air and spacecraft and related machinery
30.40	Manufacture of military fighting vehicles

	High-value technology
20.13	Manufacture of other inorganic basic materials and chemicals
20.14	Manufacture of other organic basic materials and chemicals
20.52	Manufacture of glues
20.53	Manufacture of essential oils
20.59	Manufacture of other chemical products n.e.c.
22.11	Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres
22.19	Manufacture of other rubber products
23.19	Manufacture and processing of other glass, including technical glassware
26.12	Manufacture of loaded electronic boards
26.40	Manufacture of consumer electronics
27.11	Manufacture of electric motors, generators and transformers
27.20	Manufacture of batteries and accumulators
27.40	Manufacture of electric lighting equipment
27.51	Manufacture of electric domestic appliances
27.90	Manufacture of other electrical equipment
28.11	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
28.12	Manufacture of fluid power equipment
28.13	Manufacture of other pumps and compressors
28.15	Manufacture of bearings, gears, gearing and driving elements
28.23	Manufacture of office machinery and equipment (excluding computers and peripheral equipment)
28.24	Manufacture of power-driven hand tools
28.29	Manufacture of other general-purpose machinery n.e.c.
28.30	Manufacture of agricultural and forestry machinery
28.41	Manufacture of machine tools
28.49	Manufacture of other machine tools
28.93	Manufacture of machinery for food, beverage and tobacco processing
28.94	Manufacture of machinery for textile, apparel and leather production
28.95	Manufacture of machinery for paper and paperboard production
28.99	Manufacture of other special-purpose machinery n.e.c.

29.10	Manufacture of automobiles and engines
29.32	Manufacture of other parts and accessories for motor vehicles
30.20	Manufacture of railway vehicles
32.50	Manufacture of medical and dental instruments and supplies

KNOWLEDGE-INTENSIVE INDUSTRIAL SERVICES WZ 2008 (3-DIGIT CLASSES)

	Knowledge-intensive services
	Emphasis on finances and assets
411	Development of building projects
641	Monetary intermediation
642	Activities of holding companies
643	Trusts, funds and similar financial entities
649	Other financial service activities, except insurance and pension funding
651	Insurance
652	Reinsurance
653	Pension funding
661	Activities auxiliary to financial services, except insurance and pension funding
663	Fund management activities
681	Buying and selling of own real estate
683	Real estate activities on a fee or contract basis
774	Leasing of intellectual property and similar products, except copyrighted works
	Emphasis on communication
611	Wired telecommunications activities
612	Wireless telecommunications activities
613	Satellite telecommunications activities
619	Other telecommunications activities
620	IT services
631	Data processing, hosting and related activities, web portals
639	Other information service activities
	Emphasis on technical consulting and research
711	Architectural and engineering activities and related technical consultancy
712	Technical testing and analysis
721	Research and experimental development on natural sciences and engineering
749	Other professional, scientific and technical activities n.e.c.
	Emphasis on non-technical consulting and research
691	Legal activities
692	Accounting, bookkeeping and auditing activities; tax consultancy
701	Administration and management of companies and plants
702	Public relations and business consultancy
722	Research and development in the area of law, economics and social sciences, as well as humanities
731	Advertising
732	Market research and public opinion polling
821	Office administrative and support activities
	Emphasis on media and culture
581	Publishing of books and periodicals; other publishing activities

582	Software publishing
591	Motion picture, video and television programme activities
592	Sound recording and music publishing activities
601	Radio broadcasting
602	Television programming and broadcasting activities
741	Specialised design activities
743	Translation and interpreting activities
823	Organisation of conventions and trade fairs and exhibitions
900	Creative, arts and entertainment activities
910	Libraries, archives, museums, botanical and zoological gardens
	Emphasis on health
750	Veterinary activities
861	Hospital activities
862	Medical and dental practice activities
869	Other human health activities n.e.c.

GLOSSARY

Alliance of Science Organisations in Germany:
The Alliance of Science Organisations in Germany is composed of the following organisations: Alexander von Humboldt Foundation, German Academy of Sciences Leopoldina, German Research Foundation, German Academic Exchange Service, Fraunhofer-Gesellschaft, Helmholtz Association, German Rectors' Conference, Leibniz Association, Max Planck Society and the German Council of Science and Humanities.

American Recovery and Reinvestment Act:
Economic stimulus package introduced by the US government during the 2009 economic and financial crisis.

Basic funds:
Basic funds refers to a university's budgetary funds including other income from grants and subsidies.

Bibliometrics:
Bibliometrics is the quantitative study of publications, authors and institutions, mostly using statistical methods. It is a subfield of scientometrics, a quantitative study of science and scientific processes.

Brain circulation:
Internationally mobile scientists and the resulting circulation of human capital and knowledge.

Brain drain:
Loss of human capital and knowledge from a country due to the (net) migration of labour.

Brain gain:
Growth of human capital and knowledge in a country due to the (net) immigration of labour.

Clusters of Excellence:
Funding line of the Excellence Initiative (cf. ibid). The goal of the Clusters of Excellence is to bundle the research potential of the German university locations. Here the focus is on the networking and cooperation of different university institutions, as well as of universities with non-university research organisations and industrial partners. The aim is to both hone the profile of the universities as well as create excellent research and career conditions for young scientists.

Community Innovation Survey:
The Community Innovation Survey (CIS) is the European Union's major statistical instrument for surveying innovation activities in Europe. The CIS analyses the economic effects of innovation on competition, employment, economic growth, trade models, etc. based on a survey of a representative sample of companies.

Compliance costs:
The measurable costs and time costs incurred by the population, industry and public administration as a result of complying with a regulation.

Cooperation ban:

Pursuant to Article 104 b of the German constitution, the German Federal Government is prohibited from providing financial resources to support the statutory education tasks of the federal states (cooperation ban). Legislative competence for the provision of school education lies exclusively with the federal states. Under the Federalism Reform I, the joint task of "educational planning", which was anchored in the constitution until this point, was abolished. Federal and *Länder* governments can now only cooperate, based on agreements, to monitor the performance of Germany's education system in international comparisons (Art. 91b Par. 2). The Federal and *Länder* governments can cooperate in the area of university research to fund science and research projects with transregional significance, provided all states have given their consent (Art. 91b Par. 1). The framework conditions for the development of research at universities deteriorated markedly as a result of the new regulations. In the area of non-university research, the Federal Government can continue to fund facilities and projects, while funding of tertiary education institutions is confined to the funding of projects.

Counterfactual:

The term "counterfactual" is used within economics to describe, in the manner of a thought experiment, the situation that would prevail if a different decision to that actually taken was chosen. For example, what would be the wages of factual academics if they had not studied – while assuming they were employed in the same job and at the same point in time? As this situation can never be observed in fact, it is therefore counterfactual.

Curricular standard value:

The curricular standard value (*Curricularnormwert,* CNW) refers to the course-specific teaching workload (hours per week during the semester) required for the education of a student within the standard period of study. The standard value is specified in the capacity regulations *(KapVO)* of the federal states.

Cutting-edge technology:

Cutting-edge technology goods refer to R&D-intensive goods (cf. ibid) in the production of which, on an annual average, more than 9 percent of turnover is invested in research and development.

Debt capital:

Debt capital is provided to companies by capital investors for a set period. In return the capital investor expects the capital to be repaid with interest. In order to ensure the servicing of the loan, bankers require adequate planning of reliable future operating results and/or the provision of collaterals.

Diagnosis Related Groups (DRG):

Since 2004 hospital services are remunerated according to the flat-rate DRG system. In the DRG system similar treatment cases are classified in groups of cases, the Diagnosis Related Groups (DRG).

Dual-career (programme):

A service for top researchers and their partners aimed at winning employees from home and abroad for a research institution by providing the families with individual support and tailored services, thus easing relocation and acclimatisation. In the case of researcher couples the primary objective is to provide both partners with an attractive position.

Dual education system:

The term "dual education system" refers to professional training conducted in parallel at the workplace and a vocational school. The workplace training is conducted according to a clearly defined training scheme for the respective profession, and the school training is conducted according to the specifications of the respective education authority (e.g. federal state or canton).

EEG reallocation charge:
In order to cover the shortfall resulting from the difference between the revenue from the sale of EEG electricity on the stock exchange and the costs associated with the legally prescribed feed-in-tariff (cf. ibid), transmission system operators charge every electricity supply company that delivers to end customers a fee per kilowatt hour – the EEG reallocation charge.

E-government:
E-government creates the basis for provision of administrative services independent of time and place. The goal is to improve electronic communication with public administration and to enable the Federal Government, the *Länder* and the municipalities to provide simpler, more user-friendly and more efficient electronic administration services.

E-health:
E-health refers to the use of electronic, networked devices for the provision of medical care and the execution of other healthcare tasks.

E-procurement:
E-procurement is the procurement of goods and services via the internet and other information and communication systems. It is generally used by larger companies and organisations for operational purchasing.

Equity capital:
Liable capital of a company. Financial resources that are raised by the company's owners themselves, or provided by profits generated by and left within the company. Equity capital can also be obtained from external investors, i.e. in the form of venture capital.

EU-12 countries:
The countries that joined the EU between 2004 and 2007 (Bulgaria, Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia).

EU-14 countries:
The EU-15 countries (cf. ibid) excluding Germany.

EU-15 countries:
Countries that were already EU member states in April 2004 (Austria, Belgium, Denmark, Finland, France, Germany, Great Britain, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, and Sweden).

EU-27 countries:
Between 2004 and June 2013, the EU comprised 27 member states: the EU-12 countries (cf. ibid), plus the EU-15 countries (cf. ibid).

EU-28 countries:
Since July 2013, the EU comprises 28 member states: the EU-27 countries (cf. ibid), plus Croatia.

EU Research Framework Programme:
Public support for research and development in the European Union is implemented through specific programmes, each of which addresses a specific research area and usually runs for several years. These programmes are subsumed under a larger unit, the Research Framework Programme.

Executive MBA:
An Executive MBA is the degree qualification obtained on completing an extra-occupational part-time course of study, generally for university graduates with professional experience in technical, scientific or economic areas.

Excellence Initiative:
An agreement between the Federal and *Länder* governments to promote science and research at German tertiary education institutions with a view to enhancing international competitiveness. Launched in 2005, the initiative is being implemented by the German Research Foundation (*Deutsche Forschungsgemeinschaft,* DFG) and the German Council of Science and Humanities (*Wissenschaftsrat,* WR). Support is granted on the basis of three funding lines: graduate schools (cf. ibid), Clusters of Excellence (cf. ibid) and Future Concepts. The Excellence Initiative will continue until 2017.

Feed-in tariff:
Network operators are obliged to pay a fee to plant operators that generate electricity from renewable energy.

Flat rate per case:
In the DRG system the Diagnosis Related Groups (cf. ibid) are allocated numerical values which are used to calculate flat rates per case. A flat rate per case represents the flat rate remuneration received by the hospital for a treatment case.

Frascati Manual:
The OECD's Frascati Manual specifies methods for collecting and analysing data on research and development. In 1963, OECD experts met for the first time with members of the NESTI group (National Experts on Science and Technology Indicators), in Frascati (Italy), in order to define key concepts such as "research" and "development". The results of those discussions formed the basis of the first Frascati Manual. Since then, the Frascati Manual has been revised several times; the most recent edition dates from 2002.

Freedom to operate:
A freedom-to-operate analysis is performed by companies in order to check whether there are any property rights that may impede the development, manufacture and market launch of a product.

Gerok position:
Within the framework of research projects supported by the German Research Foundation (DRG), physicians have the opportunity to be temporarily relieved of their clinical duties and devote themselves exclusively to their scientific project when holding a Gerok or rotation position.

Graduate schools:
Funding line of the Excellence Initiative (cf. ibid). Graduate schools are designed to promote young scientists and create optimal research conditions for doctoral work within a broad, cross-disciplinary field of science, while simultaneously contributing to the development of a university's scientific profile.

Green ICT:
Green ICT refers to the endeavour to make the use of information and communication technology (ICT) as environmentally and resource-friendly as possible throughout its entire lifecycle.

Higher Education Pact 2020:

The Higher Education Pact 2020 is an agreement between the Federal and *Länder* governments launched in 2007 and designed to continue until 2020. It comprises three pillars: (1) the provision of courses of study that are geared to demand and needs, (2) the granting of programme allowances (cf. ibid) for research projects funded by the DFG, and (3) the Quality Pact for Teaching (cf. ibid).

High technology:

Cf. R&D-intensive goods.

High-Tech Strategy:

A policy initiative by the Federal Government to integrate innovation funding across all federal ministries. It was launched in August 2006, and revised in 2010. The High-Tech Strategy focusses in particular on the holistic management of complex technology systems, and on market relevance. A key characteristic of the strategy is that it concentrates on selected fields of innovation. Its key emphases include the horizontal design of R&I policy across ministries, aligning research and innovation more strongly to markets, and optimising relevant framework conditions. The Federal Government's High-Tech Strategy is managed by the Federal Ministry of Education and Research (BMBF).

High-value technology:

High-value technology refers to R&D-intensive goods (cf. ibid) in the production of which, on an annual average, more than 3 percent, but not more than 9 percent, of turnover is invested in research and development.

Horizon 2020:

Horizon 2020 refers to the new framework programme for research and innovation which in 2014 succeeded the 7th EU Research Framework Programme (cf. ibid). Horizon 2020 brings together all of the European Commission's research and innovation-relevant funding programmes.

IAB Establishment Panel:

The IAB Establishment Panel is a representative employer survey of corporate employment parameters. The corporate survey is conducted by the Institute for Employment Research (IAB) and the Federal Employment Agency's research facility. It covers a broad range of questions on a multitude of employment and corporate policy themes which can be used for a variety of different research projects.

Incremental innovation:

Incremental innovation refers to improvements to an existing product. In contrast to this, radical innovation (cf. ibid) refers to fundamental innovations that lead to entirely new product concepts and technical solutions.

Impact factor:

The impact factor measures the influence of an article or a scientist on the basis of the number of citations of a scientific article or journal.

Industry 4.0:

Industry 4.0 is a specific future-oriented project within the Federal Government's High-Tech Strategy (cf. ibid) designed to promote the computerisation of classical industries, e.g. mechanical engineering.

Innovation intensity:

Innovation expenditure relative to turnover.

Innovation Union Scoreboard:
The EU's annual Innovation Union Scoreboard provides a comparative performance overview of research and innovation systems in individual member states.

Job rotation:
Job rotation is the systematic change of job or tasks within a company or department.

Knowledge economy:
The knowledge economy encompasses R&D-intensive industries and knowledge-intensive services (cf. ibid).

Knowledge-intensive services:
Knowledge-intensive services are primarily characterised by a workforce with an above-average share of employees holding tertiary education qualifications.

Lead innovations:
Lead innovations are an instrument of the Federal Ministry of Education and Research (BMBF) focussed on promoting growth and employment in Germany. Lead innovations are designed to promote those sectors of the German economy with high growth dynamics.

National Electromobility Development Plan:
The National Electromobility Development Plan, launched by the Federal Government in August 2009, aims to promote the research and development, market preparation and market entry of battery-powered electric vehicles. The National Platform for Electromobility (cf. ibid) was established for the purpose of coordinating and implementing the plan.

National Hydrogen and Fuel Cell Technology Innovation Programme:
The National Hydrogen and Fuel Cell Technology Innovation Programme (NIP) is a joint programme initiated by the Federal Government, industry and science in 2006 for the promotion of hydrogen and fuel cell technologies. The NIP is designed to accelerate and prepare the market launch of these technologies.

National Platform for Electromobility:
The National Platform for Electromobility (NPE) is an advisory committee founded in May 2010 by the Federal Government composed of representatives from government, industry and science, the municipalities and consumers. The goal of the platform is to transform Germany into both a lead market and a lead provider for electromobility by 2020 (cf. National Electromobility Development Plan).

Office of Management and Budget:
An institution answering directly to the US President. Its role is to advise the president during the planning, execution and realisation of measures, as well as preparing the draft budget and safeguarding its implementation.

Open innovation:
The opening up of corporate innovation processes i.e. the active, strategic use of external sources in order to increase one's own innovation potential. In this process firms must be able to internalise external knowledge and/or to externalise internal knowledge.

Open source:
Open source or open source code refers to software that anyone may study, use, change and copy at will.

Orphan drugs:
Orphan drugs refer to pharmaceuticals for the treatment of rare diseases.

Oslo Manual:
The OECD's Oslo Manual contains specifications on the statistical coverage of innovation activities. The Oslo Manual goes beyond the R&D concept used by the Frascati Manual (cf. ibid), as it makes a disctinction between different forms of innovation. The Oslo Manual serves as the basis for the Community Innovation Surveys, which have been conducted five times in Europe to date. The most recent revision of the manual dates from 2005.

Pact for Research and Innovation:
The pact regulates the financing growth for Germany's five non-university science and research organisations as agreed by the Federal and *Länder* governments between 2011 and 2015. The science and research organisations have in turn committed themselves to improve the quality, efficiency and performance of their respective research and development activities.

PCT application:
The international patent application process was simplified in 1970 with the adoption of the Patent Cooperation Treaty (PCT) under the umbrella of the World Intellectual Property Organization (WIPO, established in 1969). Inventors from PCT contracting countries can submit prior notification of an application to the WIPO – or other registered authorities – and submit one patent application instead of several individual national or regional applications. This enables inventors to obtain patent protection in all of the 148 treaty countries. The priority date of the patent is the date the application is submitted to the WIPO. The applicant is subsequently given a 30 month (grace) period within which he or she can decide in which countries the patent protection shall apply. National or regional patent offices are nevertheless responsible for the granting of patents.

PCT inventor:
Cf. PCT application.

Peer review:
A quality assurance procedure for scientific literature. An independent expert from the same discipline as the author assesses the scientific value of the author's publication.

Programme allowance:
Programme allowances represent the second pillar of the Higher Education Pact 2020 (cf. ibid). Prior to the introduction of the pact it was the responsibility of the tertiary education institutions to meet the overhead costs for the implementation of a project. Now applicants for projects funded by the German Research Foundation (DFG) receive a programme allowance to cover the indirect additional and variable costs connected with the funding. This amounts to 20 percent of the accountable direct project costs.

Project allowance:
Since 2011, the Federal Ministry of Education and Research (BMBF) has granted a 20 percent project allowance for direct project funds to tertiary education institutions.

Quality Pact for Teaching:

In June 2010 the Federal Government and the *Länder* launched the "Programme for better study conditions and improved teaching quality" which will run until 2020. The Higher Education Pact 2020 (cf. ibid) thus received a third pillar. This funding line is not designed to improve the supervision of students and the quality of teaching across the broad university landscape – the special focus of the programme is to improve university staffing for teaching, supervision and advice and to provide further training for existing personnel.

Radical innovation:

Fundamental innovations that lead to entirely new product concepts, technical solutions or services – in contrast to incremental innovation (cf. ibid), which refers to the improvement of an existing product or process.

RAND experiment:

US study of households from six different regions in the United States with a random distribution of different health plans conducted in the period between 1974 and 1981. The primary interest of the study was how the health expenditure of households changed according to different levels of cost-sharing.

Randomised experiments:

Procedure for determining the causal effects of measures in which study participants are randomly allocated to a treatment and a control group. This ensures that participants in the treatment and control group only differ with respect to the measure.

Research and Development (R&D):

The OECD's Frascati Manual (cf. ibid) defines research and development as systematic, creative work aimed at expanding knowledge – also with the objective of developing new applications.

Research and Innovation (R&I):

Research and development (R&D) and R&I are not used synonymously. According to the OECD's Frascati Manual (cf. ibid), the term R&D comprises the three areas of basic research, applied research, and experimental development. Thus R&D refers to only one aspect of R&I activities. According to the definition in the OECD's Oslo Manual (cf. ibid), innovations include the introduction of new or essentially improved products (goods and services), processes, and marketing and organisational methods. Innovation expenditure comprises spending on internal and external R&D, innovation-related machines and materials, product design, the market launch of new products, and other innovation-related goods and services.

R&D intensity:

Expenditures for research and development (R&D), as a percentage of a company's or a sector's total turnover or of a country's gross domestic product, respectively.

R&D-intensive goods:

R&D-intensive goods comprise cutting-edge technology goods (cf. ibid) and high-value technology goods (cf. ibid).

SGB organising institution:

The second book of the Code of Social Law (SGB II) regulates the basic income of unemployed persons in Germany. In accordance with the SGB II, the organising bodies are the Federal Employment Agency on the one side, and as municipal organising bodies, the administrative districts and self-governing cities on the other. Each organising body must comply with a specific statutory catalogue of tasks. The responsibilities associated with its implementation are guaranteed by Article 91e of the German constitution and the cooperation between the Federal Government, the *Länder* and the municipalities is specified therein.

Smart grids:

A smart grid refers to an intelligent electricity network employing modern information and communication technology, e.g. for the grid integration of decentrally-generated energy, for the optimisation of load management or customer-side energy management.

Smart specialisation:

Smart specialisation is a European Union strategy for European regions that guides the development of regional innovation strategies for the funding period 2014 to 2020.

Span of management:

The span of management denotes the number of subordinates that a person in a senior management position directs and for whom they must assume responsibility.

Spillover effects:

Spillover effects occur in research and innovation in the form of knowledge transfer, e.g. when a company generates economic benefits from R&D activities of another company.

Start-ups:

Newly established businesses.

Teaching load hours:

Teaching load hours are a unit of measure for a (university) teacher's lecture duties.

Third-party funding:

Third party funding is university or other research institution funding acquired from public or private sources in addition to the regular budget (basic or institutional funding).

Three-percent target:

In 2002, the European Council decided in Barcelona that the EU's R&D expenditures shall be increased to three percent of a country's GDP by 2010. In addition, two-thirds of the relevant expenditure are to be financed by the private sector.

Transnational patents:

Inventions that are the subject of at least one application filed with the World Intellectual Property Organization (WIPO) (cf. PCT application) through the PCT process, and one application filed with the European Patent Office (EPA). Such patents are particularly important for the export-based German economy, as they secure the protection of inventions beyond the domestic market.

Value added:

Total of all factor income generated (wages, salaries, interest, rent, lease income, sales profits) in a given period included in the national accounts. The term is equivalent to national income (national product). In a business sense, value added refers to the production value generated in a given period, minus the value of the preliminary work/services received from other companies in the same period.

Venture capital:

Venture or risk capital refers to initial capital for start-up businesses and young enterprises provided as equity capital. It also includes funding used to strengthen the equity capital bases (cf. ibid) of small and medium-sized enterprises. This enables such companies to roll out activities and to implement innovative, even very risky projects. For investors, venture capital investments are also associated with high risk. This is why venture capital is also referred to as risk capital. Venture capital is often provided by special venture capital companies (capital investment companies). Venture capital investment can be divided into the seed phase, the start-up phase, and the later stage phase.

RECENT STUDIES ON THE GERMAN INNOVATION SYSTEM

The Commission of Experts for Research and Innovation (EFI) regularly commissions studies on topics that are relevant in terms of innovation policy. All studies can be found on the EFI website (www.e-fi.de) under the section "Studies on the German innovation system". The findings of these studies have been integrated into the EFI Report.

1-2014 Baethge, M.; Cordes, A.; Donk, A.; Kerst, C.; Leszczensky, M.; Meister, T.; Wieck, M. (2014): Bildung und Qualifikation als Grundlage der technologischen Leistungsfähigkeit Deutschlands 2014 – Schwerpunkt: Neue Konstellation zwischen Hochschulbildung und Berufsausbildung, Studien zum deutschen Innovationssystem, Berlin: EFI.

2-2014 Schasse, U.; Belitz, H.; Kladroba, A.; Leidmann, M.; Stenke, G. (2014): Forschungs- und Entwicklungsaktivitäten der deutschen Wirtschaft, Studien zum deutschen Innovationssystem, Berlin: EFI.

3-2014 Müller, B.; Gottschalk, S.; Niefert, D.; Rammer, C. (2014): Unternehmensdynamik in der Wissenswirtschaft in Deutschland 2012 – Gründungen und Schließungen von Unternehmen, Gründungsdynamik in den Bundesländern, Internationaler Vergleich, Studien zum deutschen Innovationssystem, Berlin: EFI.

4-2014 Neuhäusler, P.; Rothengatter, O.; Frietsch, R. (2014): Patent Applications – Structures, Trends and Recent Developments 2013, Studien zum deutschen Innovationssystem, Berlin: EFI.

5-2014 Michels, C.; Fu, J.; Neuhäusler, P.; Frietsch, R. (2014): Performance and Structures of the German Science System 2013, Studien zum deutschen Innovationssystem, Berlin: EFI.

6-2014 Schiersch, A.; Gehrke, B. (2014): Die Wissenswirtschaft im internationalen Vergleich: Strukturen, Produktivität, Außenhandel, Studien zum deutschen Innovationssystem, Berlin: EFI.

7-2014 Loos, S.; Albrecht, M.; Sander, M.; Schliwen, A. (2014): Forschung und Innovation in der Hochschulmedizin, Studien zum deutschen Innovationssystem, Berlin: EFI.

8-2014 Frietsch, R.; Neuhäusler, P.; Michels, C.; Dornbusch, F. (2014): Medical Research at Universities – An International Comparison, Studien zum deutschen Innovationssystem, Berlin: EFI.

9-2014 Schiller, D. (2014): Machbarkeitsstudie: Forschermobilität und Innovation, Studien zum deutschen Innovationssystem, Berlin: EFI.

10-2014 Cordes, A.; Schiller, D. (2014): Forschermobilität und qualifizierte Zuwanderung in Deutschland und den USA - Eine Analyse aktueller nationaler Mikrodaten, Studien zum deutschen Innovationssystem, Berlin: EFI.

11-2014 Gehrke, B.; Cordes, A.; John, K. (NIW); Frietsch, R.; Michels, C.; Neuhäusler, P. (Fraunhofer ISI); Pohlmann, T. (TU Berlin); Ohnemus, J.; Rammer, C. (ZEW) (2014): Informations- und Kommunikationstechnologien in Deutschland und im internationalen Vergleich – ausgewählte Innovationsindikatoren, Studien zum deutschen Innovationssystem, Berlin: EFI.

12-2014 Ihsen, S.; Schiffbänker, H.; Holzinger, F.; Jeanrenaud, Y.; Sanwald, U.; Scheibl, K.; Schneider, W. (2014): Frauen im Innovationsprozess. Aktuelle Entwicklungen, internationale Perspektiven, Handlungsempfehlungen, Studien zum deutschen Innovationssystem, Berlin: EFI.

13-2014 Czernich, N. (2014): Forschung und Entwicklung deutscher Unternehmen im Ausland – Zielländer, Motive und Schwierigkeiten, Studien zum deutschen Innovationssystem, Berlin: EFI.

14-2014 Dauchert, H.; Schneider, J. (2014): Aktuelle Entwicklung der Forschungsaktivitäten zur Elektromobilität, Studien zum deutschen Innovationssystem, Berlin: EFI.

15-2014 Meurer, P. (2014): Diskussion zur Weiterentwicklung des deutschen Wissenschaftssystems, Studien zum deutschen Innovationssystem, Berlin: EFI.

ENDNOTES

A 1 1 Cf. Allianz der Wissenschaftsorganisationen (2013), DFG (2013a), FhG (2013), HGF (n.y.) HRK (2013a), HRK (2013b), MPG (2013), WGL (2013), Wissenschaftsrat (2013a). For an overview, cf. Meurer (2014).

2 Cf. EFI (2012: 34ff.). According to a recent study by the Donors' Association for the Promotion of Sciences and Humanities in Germany (Stifterverband für die Deutsche Wissenschaft 2013: 44ff.), the current mix of basic funds and third-party funds is deemed appropriate by the majority of university heads. Yet, a different picture appears with regard to technical universities and so-called elite universities, where the share of third-party funds is higher than the average ratio recorded for tertiary education institutions. Here, heads of universities would like the proportion of basic funds to be higher.

3 Cf. CDU, CSU and SPD (2013).

4 Cf. CDU, CSU and SPD (2013: 88).

5 Programme allowances are granted as part of the Higher Education Pact's second pillar.

6 Cf. Meurer and Schulze (2010).

7 This objective represents the Higher Education Pact's first pillar.

8 The Quality Pact for Teaching constitutes the third pillar of the Higher Education Pact.

9 Cf. CDU, CSU and SPD (2013: 26).

10 Cf. CDU, CSU and SPD (2013: 27).

11 Cf. in the following EFI (2012: 48, 57).

12 Cf. Meurer (2014).

13 Cf. CDU, CSU and SPD (2013: 27, 89).

14 Cf. EFI (2011: 36ff.).

15 Cf. HGF (n.y.)

16 Cf. EFI (2013: 34ff.).

17 Cf. EFI (2011: 36ff.).

A 2 18 Cf. Staatssekretärausschuss Bürokratieabbau (2013).

19 Many exemplary evaluations stem from the field of labour market policy, an area in which it is particularly easy to implement evaluation measures. In France, an exemplary project was conducted to investigate whether intensive consultation provided to unemployed juveniles increased their chances on the labour market. A two-staged randomised procedure was employed to assess the effectiveness of the measure. First, the number of juveniles to be supported in each region was randomly selected. In each of the regions, the juveniles to receive consultation were then randomly selected. Based on this two-staged randomised procedure, it was possible to divide the juveniles into three distinct groups: youths from region A who received consultation, youths from the same region A who did not receive consultation, and youths from the neighbouring region B, in which nobody received consultation. The evaluation revealed that, eight months after the measure, those juveniles who had received consultation had a 2.5 percent higher chance of long-term employment than juveniles from the same region who had not received consultation. A direct comparison thus suggests that the juveniles benefitted from the consultation services. At the same time, however, the juveniles from region A who had not received consultation had a 2.1 percent lower chance of long-term employment than the juveniles from the neighbouring region B, in which no one had received consultation. This means that the positive effect on employment for juveniles with consultation went almost entirely at the expense of juveniles in the same region without consultation. Hence the provision of consultation services was no real success but only led to a redistribution of jobs. Cf. Crépon et al. (2013).

20 Cf. Krueger (1999).

21 Cf. e.g. Aron-Dine et al. (2013).

22 The HighScope Perry Preschool Program may serve as a pioneering example of how scientific studies can also lead to evidence-based policy: a randomised experiment among children of poor families was used to assess the effects of early childhood education on a number of short-term and long-term results.Cf. Heckman et al. (2010).

23 The OMB reports directly to the President. It advises the President in the planning, execution and implementation of measures and prepares the President's draft budget and ensures its implementation. The OMB reviews all measures suggested by other authorities and establishes whether these are compatible with the President's own objectives. One of these objectives is the introduction of evidence-based policies. In the field of evaluations, the OMB therefore monitors evaluations of all authorities and the decisions to be taken based on these evaluations. Cf. OMB (2013a).

24 Cf. OMB (2013b: 92).

25 Examples exclude the "home visiting" initiative in which social workers or other professionals visit socially disadvantaged families in their homes to support the development of their children. As part of the US government's home visiting initiative, a three-staged process to promote these programmes has been created. In the first stage, all of the federal states could propose packages of measures, which received initial funding and were subsequently evaluated. The second stage required the states to submit their further financing requirements and the results of the evaluations. The third stage, which serves to finance the expansion of the programmes, is based on these evaluations. The federal states were then obliged to expend at least 75 percent of the allocated funds on one of the measures deemed effective by an appointed research institute. The remaining funds may be expended on promising measures that have not yet been evaluated. Cf. Haskins and Baron (2011).

26 Cf. United States Department of Labor (2013).

27 Cf. e.g. Krueger (1999).

28 As of 17 December 2013.

29 A similar objective is pursued by the Top Institute for Evidence Based Education (TIER) in the Netherlands. The institute, an umbrella organisation of several academic facilities and government institutions, aims to gather research from the field of educational policy, implement their own research and assess existing research findings in this policy area.

30 Cf. Haynes et al. (2012).

31 Cf. Cabinet Office (2013), 1 May 2013.

32 Cf. e.g. Lanser and van Dalen (2013).

33 Cf. Cornet et al. (2006).

34 On the first relevant day of drawing alone, 1,044 applications were made for 100 vouchers.

35 Cf. Bos and Teulings (2010).

36 Ethical concerns that have been expressed regarding experiment-based evaluations in particular can be resolved by simple means (cf. EFI 2013). Especially for programmes that cannot be immediately implemented in full for budgetary or other reasons, it is recommended to launch the programme in stages and to combine it with an in-depth evaluation. The easiest way of implementing scientific evaluations is achieved through the realisation of economic policy measures at different points in times. This is often necessary in any case, and it can be used to create suitable comparison groups.

37 If this is not done, one runs the risk that measures merely implement those aspects that are measurable, and that those objectives of a measure that cannot be quantified as easily will not be accomplished (cf. Lazear 2006).

38 In order to derive meaningful results from evaluations, it is essential that all factors except for the measure to be examined can be excluded as the reason for the results. Randomised experiments have become the "gold standard" for achieving this goal (cf. EFI 2013). This means that the support measure is randomly assigned, thus treatment and control groups do not differ systematically. However, alternative methods can also help determine the causal effects of a support measure. Regression discontinuities exploit the fact that there is a threshold (e.g. a company's turnover) for receiving the support measure. Whether a company is just above or just below the support threshold is often a matter of coincidence. The comparison of companies just above and just below the

threshold should therefore be at random and should allow to determine the support measure's effect. Other guidelines for support measures can also be employed. It is important, however, that these have no direct impact on the results of the company, while still affecting the probability of obtaining support (so-called instrumental variables). On average, different companies should then only differ in terms of their level of support, which allows the identification of the measure's effect. The gradual introduction of support measures can also be used as a means of evaluating a measure. Here it is important that the development of funded and non-funded companies is similar apart from the support received. To determine the effect of the measure, it will then suffice to compare both groups before and after the support measure (double-differences approach).

A 3

39 Cf. Baethge et al. (2014: 1). The particular importance of the interaction between graduates from tertiary education institutions and graduates from the dual training system for the innovative capacity of Germany's industry sector has also been stressed in a recent study by the Massachusetts Institute of Technology (MIT) "Making in America: From Innovation to Market". Cf. Berger and MIT Task Force on Production and Innovation (2013), Backes-Gellner and Teuber (2012) and Backes-Gellner et al. (2011) also point out the importance of an optimal mix of academics and skilled workers in order to harmonise different skills, information and decision-making powers.

40 Thus, Aghion and Howitt (2006), as well as Krueger and Kumar (2004) argue that only academic qualifications are suitable drivers of innovation and growth for economies on the technological frontier, while vocational training may at best be useful for economies that are far behind the technological frontier and only for innovations that are based on old and established technologies. However, the simplistic distinction between highly qualified academics on the one hand and low-skilled vocational graduates on the other hand does not account for countries with an advanced high-quality dual vocational training system such as Germany or Switzerland. In these countries, e.g. dual training for polymechanics is based on a highly demanding four-year (schooling and company-based) curriculum (cf. Ryan et al. 2010), and e.g. the mathematics requirements in technical professions are in no way inferior to those of university students in other countries (cf. Bierhoff and Prais 1997).

41 Such geographic proximity is highly advantageous for innovation, ranging from the development of a product idea to the product's further technical specifications, and from design ideas to fast prototyping (cf. Berger 2013: 128 – 132).

42 Teuber et al. (2013) have shown that subsidiaries of US enterprises in Germany – or in Switzerland, which has an educational system that is very similar to that of Germany – do not always opt for a "typical American way" for radical innovations (focussing on university graduates and numerical flexibility), but instead make use of local advantages, while focussing on a mix of vocational and higher education graduates, coupled with functional flexibility.

43 Cf. Rupietta and Backes-Gellner (2013), Teuber (2013).

44 Cf. Backes-Gellner (1996), Rupietta and Backes-Gellner (2012).

45 Cf. Backes-Gellner and Tuor (2010).

46 In a comparison between Germany, Great Britain, France and Luxembourg, Backes-Gellner (1996) has also shown that, in German companies, radical process innovation disseminates much faster through the entire production process due to the profound and future-oriented design of skilled worker training in Germany. It could also be shown that German companies are more successful in systematically exploiting their flexibility potential than companies in Great Britain, France or Luxembourg. According to a study by Arnold (2002), German mechanical engineering companies managed to achieve a competitive advantage over their international competitors in the early 1990s by rapidly adopting innovative PC-based CNC (computer numerical control).

47 Dustmann and Schoenberg (2008) provide three important determinants of the effectiveness of Germany's education system: strong labour market institutions (especially trade unions), a reduced level of asymmetric information, and complementarities between specific and general human capital.

48 In the United States, only a few large corporations participate in providing systematic company-based training (cf. Berger 2013: 196).

49 Cf. BIBB (2013: 223). Culpepper and Thelen (2008) however, argue that companies from the services sector in particular only rarely participate in dual education, and that there are no convincing strategies to be detected for persuading service companies of the advantages of participating in the dual education system (cf. Culpepper and Thelen 2008: 37f.; 42). Yet, there is a lack of systematic empirical evidence on this issue, and initial evaluations by Demgenski and Icks (2002) suggest that dual training can gain a foothold relatively quickly even in young industries and enterprises. That said, it has been observed that the expansion of academic study courses has led to an academisation trend in a number of professions, which subsequently led to an academisation of employees. Yet, it is not clear whether this said trend is largely induced by the supply or demand side.

50 Cf. Laur-Ernst and King (2000).

51 Cf. Deutscher Bundestag (2013: 31–32). The new IT professions were developed by the Federal Institute for Vocational Education and Training (BIBB), in collaboration with experts from the industry, and in parallel to the dynamic developments in the ICT sector (cf. BIBB 2013: 405). For a detailed account of the process of formulating new training regulations, cf. BIBB (2011).

52 Cf. Demgenski and Icks (2002).

53 For a comprehensive account of trends and forecasts, cf. Baethge et al. (2014).

54 Cf. Leszczensky et al. (2011: 53f.).

55 Thus, the growing number of school graduates also led to the fact that the number of persons with double qualifications – i.e. first-year students at universities or universities of applied sciences who had completed vocational training after obtaining the higher education entrance qualification – continued to increase since the 1980s (from about 50,000 to 81,000), even though their percentage share had declined significantly over the same period (from approx. 20 percent to 11 percent at universities and from approx. 50 percent to 40 percent at universities of applied science) (cf. Baethge et al 2014: 31). Thus, as regards persons with double qualifications, actual bottlenecks resulting from these structural shifts have not been detected yet.

56 Surveys among persons with higher education entrance qualification show that today only 3 percent of persons with higher education entrance qualification strive for double qualification. In 1990, approximately 12 percent of all persons with higher education entrance qualification strived for double qualification. Persons with double qualifications are defined as follows: individuals eligible to tertiary education who, upon gaining their higher education entrance qualification, first complete vocational training and only then take up an academic degree course. The traditional model in this regard has been the upper secondary school graduate who completes vocational training as a banker, followed by a degree course in business administration (cf. Heine et al. 2010: 84).

57 First-year students at German dual universities account for only 4 percent of all newly enrolled students. Around half of these are students of the former universities of cooperative education in the federal state of Baden-Württemberg (cf. Baethge et al 2014: 37). A comprehensive study on ways of strengthening the ties between the higher education system and the dual vocational training system, e.g. through work-study programmes, has been presented by Graf (2013) based on a comparison between Germany, Austria and Switzerland. Graf concludes that such newly created hybrid institutions simply represent a new form of permeability, while at the same time constituting a new premium sector that is characterised by greater social prestige and better labour market prospects. However, the newly emerging hybrid institutions in these three countries seem to be unparalleled in Europe as they require a strong education system of a type that cannot be found in either France, England, or the United States (cf. Graf 2013). An anthology published by the Federal Institute for Vocational Education and Training (BIBB) provides a comprehensive overview of the recent discussion on the potential blurring of demarcation lines between vocational and academic training, and the implications leading from this (cf. Severing and Teichler 2013).

58 In this context, the growing pressure on traditional vocational training has often been interpreted as a result of technological progress. However, Autor (2013) shows that even against the background of continuing technological progress, middle skill jobs are not disappearing, but might even gain

importance in future. Middle skill jobs are jobs that combine tasks from different skills and high-quality multi-year vocational training, but not an academic degree course.

59 For a critical analysis of this issue, cf. Backes-Gellner (1999a and 1999b). As early as 1997, Harhoff and Kane (1997) pointed out that graduates from vocational training in Germany receive a salary level comparable to that of high school graduates in the United States.

60 A greater international interest in dual vocational education has emerged only recently with the dramatic rise in youth unemployment in some countries and comparatively low youth unemployment in countries with a dual vocational education system. This increased interest is also reflected e.g. in the OECD's new focus of "Learning for Jobs".

61 Since the structure of the dual training regulations and the quality of education standards are very similar in Switzerland and Germany and thus produce comparable qualifications in both the dual system and the higher education system, it can be assumed that the labour market effects following dual training and studying in Switzerland and Germany are similar in structure.

62 Cf. Balestra and Backes-Gellner (2013).

63 In this context, talent is defined very broadly and may include analytical and linguistic skills (e.g. measured on the basis of IQ), but also psychological features such as stamina, motivation or self-regulation.

64 It could be shown that career changes within relatively large occupational clusters with similar skills sets are accomplished quite easily and even go hand in hand with a rise in income (cf. Geel et al., 2011). Thus, as long as vocational training provides participants with a skills set that is also required in other professional fields – which is indeed the case in most vocational training courses – it does not only facilitate an excellent start into professional life, but also opens up a wide range of options in the long term. As a rule, a higher number of years in education will offer better protection against involuntary dismissal, and yet, higher education pathways are not better but as good as advanced vocational training pathways (cf. Balestra and Backes-Gellner 2012).

65 Cf. Tuor and Backes-Gellner (2010).

66 Cf. Tuor and Backes-Gellner (2010). For an overview of recent findings on the comparison between the Swiss vocational training system and academic training courses, cf. Backes-Gellner and Brunner (2012).

67 Cf. Janssen and Backes-Gellner (2009).

68 For a theoretical analysis of the interrelationship between incentives for parents/pupils, schools and businesses with reference to the lower secondary school system of the 1990s, cf. Backes-Gellner and Weckmüller (1998). For an empirical analysis of the balancing effect of external performance standards on the performance decline in upper secondary schools (centralised school-leaving certificate), cf. Backes-Gellner and Veen (2008), as well as Wößmann et al. (2013).

69 A large number of (partially) state-funded programmes are already in place to support disadvantaged young people and young people who did not undergo vocational training (for an overview, cf. BMBF 2013a: 52–57). In Germany, young people who do not qualify for vocational training in the dual system due to lack of a general school-leaving certification – and young people who have been unable to find a training place or have not yet completed compulsory schooling – are supported through various (transitional) educational programmes. The number of new entrants into the transition system increased to 486,000 in 2005 but has been declining since then, with 292,000 new entrants in 2012. Cf. Federal Statistical Office and the statistical offices of the *Länder*; own calculations and estimates based on school statistics; Federal Employment Agency, Bestand von *Teilnehmern in ausgewählten Maßnahmen der Arbeitsmarktpolitik mit SGB-Trägerschaft des Teilnehmers*, figures from 2011 according to *iABE Schnellmeldung* (first release of VET reporting). The "company-based entry-level qualification" programme (betriebliche Einstiegsqualifizierung) may serve as an example here, since this programme has undergone thorough methodological evaluations and has achieved the intended objectives. As part of this programme, young people with limited job perspectives gain an insight into professional practice through a six to 12 month internship, while at the same time acquiring additional skills and qualifications. The companies involved can make use

of a non-binding probation period. For these purposes, the companies involved provide for 30,000 available places annually and receive government subsidies of up to EUR 261 per month for each juvenile employed in the company. It could be shown that six months after the completion of the entry-level qualification programme, 69 percent of participants had entered into regular vocational training. The accompanying research suggests that windfall gains and the exploitation of participants as cheap labour did not seem to exist on a large scale. However, concerns have been raised concerning the lack of standards in certification, issues relating to recognition and the involvement of vocational schools (cf. Popp et al. 2012). When establishing further solutions, the effects of such company-based instruments should serve as a benchmark (cf. recommendations by Wößmann 2011, Aktionsrat Bildung 2011, DGFP 2013). In this context, it is also worth mentioning the programme for disadvantaged individuals (Programm für Benachteiligte) by Siemens AG, a pilot project for the integration of low-skilled workers into professional life with approximately 250 participants per year. With only little additional cost and burden for Siemens, and by making efficient use of existing public support options (e.g. paid tuition), participants can make up for missed opportunities, while also being fully integrated into professional life by means of an apprenticeship. Efficient transitional support should always be designed in a way that reinforces entrepreneurial activities, rather than replacing them.

70 Cf. the opinions expressed in the 2012 Report (universities need to differentiate further and focus to a greater extent on training opportunities for vocational graduates). Cf. EFI (2012: 72f.). A forward-looking approach to education policy in Germany must not only aim to ensure a high number of academics, but also needs to ensure the attractiveness of high-quality options for further training and increase the permeability of the higher education system. The further training system will have to be developed with a view on integrating especially underrepresented groups of employees and on compensating for deficits in initial training. Cf. EFI (2012: 73; 75). The focus is no longer placed on undergraduate courses, but rather on aligning the choice of courses to facilitate further qualifications for individuals in active professional life. More thought must be given not to the design of full-time undergraduate courses but to innovative part-time further education programmes such as CAS, DAS, MAS, Executive MBA. On the differentiation in the division of labour in the higher education system, cf. Expertenkommission Forschung und Innovation (2012: 63).

71 Regarding the recognition of skills acquired in professional life, cf. Expertenkommission Forschung und Innovation (2012: 63f; 73).

72 While this option has in fact been available for quite some time, it has gained greater political value with the resolution of the Standing Conference (KMK) in March 2009 (cf. Baethge et al. 2014: 34). A ray of hope in this regard has been the recent increase in the number of persons with professional qualifications and without a higher education entrance qualification who have taken up a course of study. While in 2000, Germany had recorded only 1,800 of such first-year students, this number increased to 12,000 in 2011 (cf. Baethge et al 2014: 34). It could be observed that persons with a background in vocational training showed an above-average participation rate in distant learning degree courses and private universities. This demonstrates the importance of non-traditional tertiary education institutions with regard to the permeability between the vocational system and the higher education system. Furthermore, it once again underlines the need to enhance differentiation within the higher education system.

73 For a comprehensive discussion of this issue, cf. Heublein et al. (2012).

74 Cf. ZDH (2013). In this regard, the initiatives launched by the Chambers of Crafts (Handwerkskammern) in Aachen and Lower Franconia may serve as a prime example. The RESET programme of the Chamber of Crafts Aachen in cooperation with the FH Aachen and RWTH Aachen provides intensive training in trades for university drop-outs and potential drop-outs while also recognising academic achievements. The pilot project *Karriereprogramm Handwerk – Studienanschluss statt Studienabbruch* initiated by the Chamber of Crafts of Lower Franconia in collaboration with the FH Würzburg-Schweinfurt and Würzburg University goes even further than that: programme participants receive special training at a vocational school and can even complete further education

modules leading up to the master craftman's certificate already during the condensed training period (cf. ZDH 2013: 13ff.).

A 4 75 The development of the knowledge economy in international comparison are presented in detail in Schiersch and Gehrke (2014).

76 Cf. Schiersch and Gehrke (2014).

77 Cf. Figure 30 in Chapter B 3.

78 Cf. the studies by Jorgenson et al. (2006), Oliner et al. (2007), as well as Timmer et al. (2013).

79 Cf. Schiersch and Gehrke (2014).

80 Cf. the comprehensive country comparisons provided by Schiersch and Gehrke (2014).

81 The relation between information and communication technologies and productivity is presented in Chapter B3 of the 2014 Report. Numerous empirical studies illustrate structural differences between the United States and Europe in particular. Cf. e.g. Brynjolfsson and Saunders (2010), as well as Timmer et al. (2013). According to these studies, ICT investments will only lead to the desired productivity effects in digital technologies when combined with organisational development processes.

A 5 82 The following section is based on Wissenschaftsstatistik (2013) unless otherwise stated.

83 The development of foreign R&D expenditure of German companies is presented in detail in Schasse et al. (2014).

84 This section and the following sections on the results of the special survey are based on Czernich (2014). The study provides detailed information on the design of the survey, the sample, as well as the selection issues, while also presenting further results of the survey.

85 672 companies were included in the survey. From among these, 113 were active in foreign R&D.

86 BRIC comprises the following countries (number of observations per country in brackets): Brazil (7), Russia (7), India (18), China (28).

87 Companies were asked to assess the following motives as very important, important, less important or not important at all: tapping of new markets, savings in wages and non-wage labour costs, financing advantages, tapping of specific knowledge or skilled workers in the target country, lower regulatory requirements in the target country, and the political requirements set by the target country's government. For this analysis, the assessments "very important" and "important" have been subsumed as one. In the following, the term "relevant" includes the responses "important" and "very important".

88 The relevant unit for the number of responses are company * target country observations.

89 EU-14 comprises the following countries (number of observations per country in brackets): Belgium (4), Denmark (1), Finland (1), France (23), Great Britain (21), Ireland (1), Italy (13), Luxembourg (1), The Netherlands (17), Sweden (10), Spain (9), Austria (18), Portugal (no observations), Greece (no observations).

90 Eastern Europe comprises the following countries (number of observations per country in brackets): Bulgaria (3), Poland (11), Romania (5), Russia (7), Serbia (2), Slovakia (4), Czech Republic (5), Ukraine (2), Hungary (3), Belarus (1).

91 The companies were provided with the following assessment categories: difficulties in processing and granting property rights, insufficient enforcement of property rights, insufficient training of academics, insufficient training of skilled workers, cultural or language barriers, poor infrastructure, poor conditions for business operations, issues with R&D cooperation partners, and issues with other local partners.

92 The EU Commission's study (2012) on the internationalisation of R&D shows that Germany occupies a relatively central position both as a target country and as a source country for the internationalisation of R&D within Europe. Cf. also Chapter B 2 of the 2013 Report.

93 Cf. Schasse et al. (2014).

A 6 94 Cf. BMBF (2011): introductory chapter of the Government Programme Electromobility *(Regierungsprogramm Elektromobilität)*.

95 In 2011, gross value added in the area “automobile and automobile components” amounted to EUR 84 billion. The value for the manufacturing industry as a whole amounted to EUR 530 billion. Cf.https://www.destatis.de/DE/Publikationen/Thematisch/VolkswirtschaftlicheGesamtrechnungen/Inlandsprodukt/InlandsproduktsberechnungEndgueltigPDF_2180140.pdf?__blob=publicationFile (last accessed on 10 January 2014).

96 Cf. Legler et al. (2009).

97 Cf. BMBF (2009b).

98 Cf. Nationale Plattform Elektromobilität (NPE).

99 Cf. http://www.foerderinfo.bund.de/de/221.php (last accessed on 10 January 2014).

100 The model regions have been funded by the BMVBS since 2008 to the tune of EUR 130 million. Cf. BMVBS (2011).

101 Up until 2015, approx. EUR 180 million will be allocated to the showcase projects (partners include BMWi, BMVBS/BMVi, BMU and BMBF). Cf. Schaufenster Elektromobilität (2012).

102 The three R&D ventures subsumed under “lighthouses” will receive more than EUR 1.1 billion in financing (battery – 28 consortia: EUR 601 million; drivetrain technology – 28 projects: EUR 230 million; vehicle integration – 6 projects: EUR 113 million; lightweighting – 8 projects: EUR 100 million; recycling – 2 projects: EUR 90 million; ICT – 17 projects: EUR 125 million). In addition, ongoing projects have also been integrated into the lighthouses. Funds will be provided by the public sector (approx. 40 percent) and the private sector. Cf. Nationale Plattform Elektromobilität (2012: 3ff.).

103 Cf. Nationale Plattform Elektromobilität (2012: 3).

104 Cf. Schott et al. (2013: 7).

105 Cf. EFI (2011: 34).

106 Cf. EFI (2010: 82).

107 Cf. Wietschel et al. (2013)

108 The updated analysis considers transnational patent applications only, while the 2010 EFI Report also included national patents.

109 Cf. TAB (2012: 70ff.).

110 Cf. http://www.economist.com/blogs/schumpeter/2013/02/hydrogen-powered-cars (last accessed on 10 January 2014).

111 Cf. http://www.now-gmbh.de/de/mobilitaet/mobilitaet-von-morgen/autos-busse-und-oeffentliche-tankstellen/h2-mobility-aufbau-eines-wasserstofftankstellennetzes-fuer-deutschland.html (last accessed on 10 January 2014).

112 With the help of power-to-gas technologies, power from renewable energies can be converted into hydrogen or synthetic natural gas and stored in the natural gas network, thereby providing a means of storing large amounts of power from renewable energy sources in the long term. Cf. http://www.powertogas.info/power-to-gas/strom-in-gas-umwandeln.html (last accessed on 10 January 2014).

113 Cf. BMVBS (2011).

114 Cf. Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie (2012).

115 The National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP) integrates all research and application areas relating to fuel cells. Besides electromobility, this includes e.g. fuel cells for stationary use or portable applications. The NIP is divided into four programme areas: transport and hydrogen infrastructure, hydrogen provision, stationary energy supply, and special markets. Cf. http://www.now-gmbh.de/de/ueber-die-now/foerderprogramme/nationalesinnovationsprogramm-nip.html und http://www.now-gmbh.de/fileadmin/user_upload/RE_Publikationen_NEU_2013/Publikationen_NOW_Berichte/NOW_Jahresbericht_2012_DE.pdf (last accessed on 10 January 2014).

116 All types of fuel cells (stationary, mobile, and portable) are considered in the patent and publication analyses.

117 Cf. Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie (2012: 10).

118 Cf. TAB (2012: 21ff.).

119 Cf. CDU, CSU and SPD (2013: 19).

120 Cf. CDU, CSU and SPD (2013: 44).

A 7 121 Cf. EFI (2013: 55, Box 14) for a detailed description of the EEG regulations.

122 Cf. BMU (2013).

123 Cf. BMU (2013).

124 Another concern regarding the EEG is the fact that its distributive effects are regressive: relative to their income, low-income households are burdened to a greater extent by the EEG reallocation charge than high-income households. Furthermore, real property owners, which tend to belong to a more affluent segment of the population, benefit from the EEG payments as property owners receive subsidies for rooftop solar panels.

125 Cost-efficient alternatives for emission prevention, such as energy-saving measures or an increased use of gas in energy generation, are being marginalised by more cost-intensive options, in this case the extreme expansion of renewable energies, cf. EFI (2013: 48).

126 Industry and labour market policy objectives hardly justify the EEG either. Cf. EFI (2013: Chapter B 1).

127 Econometric studies with a focus on international comparisons have partially identified positive links between innovation activities in the field of renewable energy and government intervention on the demand side over the last 30 years. Individual studies on wind power and photovoltaics have also identified positive effects on national innovation activity through foreign demand-side support measures. However, what all of these studies have in common is the fact that aggregated effects are considered across several countries, and/or that observation periods started well before the introduction of the EEG in 2000. Furthermore, most studies do not differentiate between demand-side policy instruments, and especially fixed feed-in tariffs are not considered separately. Cf. Johnstone et al. (2010), Peters et al. (2012), Walz et al. (2011), Dechezleprêtre and Glachant (2013), as well as Hoppmann et al. (2013).

128 Cf. Wangler (2012).

129 An increasing demand relative to total electricity consumption, as well as increasing consumer prices for electricity lead to a much more pronounced increase in patent applications. Cf. Böhringer et al. (2013).

130 In contrast, competition between technology suppliers can provide incentives for the cost-efficient improvement of existing technologies. Associated incremental innovations are not always fully recorded in the patent statistics.

131 Cf. Hoppmann et al. (2013).

B 1 132 BMBF (2006a).

133 On public and private R&D expenditure, cf. http://www.researchamerica.org/uploads/healthdollar07.pdf (last accessed on 10 January 2014), as well as http://www.researchamerica.org/uploads/healthdollar12.pdf (last accessed on 10 January 2014). On the NIH research budget, cf. http://www.nih.gov/about/budget.htm (last accessed on 10 January 2014). On the United States' GDP, cf. International Monetary Fund (2013).

134 On Germany's GDP, cf. International Monetary Fund (2013). On the DFG's and DLR's expenditure on medical research, cf. DFG (2012: 162) and cf. DLR (2013: 18).

135 Cf. BMG (2013: 133) and BMG (2009).

136 A multi-level, data-based procedure was used to establish the strongest university medicine locations. The analysis was designed in a way that facilitates international comparison and comprises university medicine research locations in Germany, Canada, the Netherlands, Switzerland and the United States. An innovative process was used for the selection of locations to be analysed: in a first step, a country's strongest research institutions were identified with the help of a publication output ranking. This was done not only by recording the number of publications of the respective university medical research location – which would represent a purely quantitative approach – but also by including the quality of publications as measured by citations. Based on the ranking, the strongest research institutions were selected for each of the above countries. These were then to be compared with each other with the help of detailed publication and patent-related indicators. In addition to a

detailed analysis of the publication output – both in absolute terms and as a share of total publications of each country and total publications worldwide – additional qualitative indicators were also examined. These included e.g. the citation rate of each individual publication, and the share of the respective publications among the world's most frequently cited medical journals. The following types of patent applications were recorded for the purpose of the patent analysis: patents filed with EPO (European Patent Office), via the PCT (Patent Cooperation Treaty for global patent protection), with the USPTO (United States Patent and Trademark Office), the DPMA (German Patent and Trademark Office), as well as patents filed in the respective home countries. Patents assigned to the medical field have been delineated based on the list of research-intensive industries and goods. Based on Gehrke et al. (2013), the medical field comprises pharmaceutical products and drugs, medical instruments and electric medical instruments. For a more detailed discussion on the selection of locations and on the implementation of international comparisons, cf. Frietsch et al. (2014).

137 Cf. Frietsch et al. (2014).

138 The number of authors from the respective facilities was identified with the help of the Scopus database as Scopus is the only database that allows for the identification of authors via a unique ID. The Web of Science does not provide for unique author information.

139 Cf. Narin et al. (1987), Trajtenberg (1990), Harhoff et al. (1999). The number of citations that include patents from subsequent patents indicates the degree to which a patent has contributed to the development of further technologies and thus serves as an indicator for a patent's technological significance (Albert et al. 1991; Carpenter et al. 1981).

140 Publication intensity is here defined as the number of medical publications per location, per 100 authors at the respective location. In parallel, patent intensity is also measured on the basis of transnational medical patent applications per 100 authors at the respective location. The number of authors of the respective facilities was established with the help of Scopus; as also displayed in Figure 14.

141 Cf. Loos et al. (2014: 71ff.).

142 Cf. http://www.snf.ch/D/ueber-uns/Seiten/default.aspx (last accessed on 10 January 2014) and www.bfs.admin.ch/bfs/portal/de/index/.../publ.Document.163267.pdf (last accessed on 10 January 2014).

143 DFG (2013a: 2).

144 Cf. Loos et al. (2014: 74).

145 In the Netherlands, the area of medical research is coordinated by the Netherlands Organisation for Health Research and Development (ZonMw) on behalf of the NWO.

146 Cf. US Department of Commerce – Bureau of Economic Analysis: Economic growth widespread across metropolitan areas, cf. http://www.bea.gov/newsreleases/regional/gdp_metro/gdp_metro_newsrelease.htm (last accessed on 10 January 2014).

147 Most recently, Boston was once again ranked as the number one life sciences cluster – before San Diego and San Francisco/Bay Area (cf. Jones Lang LaSalle 2012). Other centres such as New Jersey/New York City have fallen in ranking due to closures of major plants.

148 In the Boston/Cambridge region, around 74,000 persons are employed in the areas of life sciences, pharmaceuticals and medical products, cf. Jones Lang LaSalle (2012).

149 Cf. Loos et al. (2014: 74).

150 Cf. Loos et al. (2014: 74).

151 The venture capital investors displayed on the map merely represent a selection of businesses active in the region and the selection does not claim to be exhaustive.

152 HGF (n.y.: 25).

153 Cf. Loos et al. (2014: 73).

154 Written statement by BMBF representatives from 6 January 2014 provided to the Expert Commission: the BMBF justifies these increased administrative requirements on the grounds that the set of rules for BMBF project funding equally applies to all research areas. According to the statement, the BMBF largely promotes application-oriented basic research or applied research, while the DFG focusses more on basic research. As a result of this application orientation, the BMBF must comply with the special documentation and control regulations in order to meet administrative and

budgetary requirements. According to the statement, project implementation may involve economic interests and – in the case of corporate projects or projects in cooperation with companies – also usage rights. Therefore, the existing regulations are ultimately governed by the provisions of EU state aid. The BMBF, which plays a significant role in co-financing the DFG, deliberately opts for different approaches to promoting science.

155 Interview with BMBF representatives on 9 December 2013 and on 10 January 2014; interview with DFG representatives on 18 December 2013; interview with DLR representatives on 28 November 2013. IGES workshop on 10 September 2013.

156 The German Council of Science and Humanities (Wissenschaftsrat) recommends diverse collaborative partnerships e.g. on the basis of experimental clauses. Cf. Wissenschaftsrat (2013a: 91f.).

157 Cf. Loos et al. (2014: 165). Cf. Charité (2013).

158 Cf. http://www.bmbf.de/de/gesundheitszentren.php (last accessed on 10 January 2014). Cf. http://www.gesundheitsforschung-bmbf.de/de/2380.php (last accessed on 10 January 2014).

159 Cf. http://www.gesundheitsforschung-bmbf.de/de/deutsche-zentren-der-gesundheitsforschung.php (last accessed on 10 January 2014), http://www.bmbf.de/de/gesundheitszentren.php http://www.bmbf.de/de/gesundheitszentren.php (last accessed on 10 January 2014).

160 The idea of assigning the functions of research and funding to one institution has been disapproved by both the DFG and the universities. The DFG has expressed the concern that a cooperation as equal partners may be jeopardised if one of the partners is also in charge of funding. Cf. Loos et al. (2014: 81).

161 Deutscher Bundestag (2010: 3f.): *Antwort der Bundesregierung.* Printed matter 17/1324. http://dip21.bundestag.de/dip21/btd/17/013/1701324.pdf (last accessed on 10 January 2014).

162 Cf. CDU, CSU and SPD (2013: 80).

163 The specialist work provided by the DZG is being gradually evaluated between 2014 and 2016. As a rule, such evaluation should be carried out every five years. Prior to the establishment of the DZG, the site selection as well as the concepts of DZG had been assessed via a two-staged procedure.

164 State budgets for R&D are illustrated by the countries' budget appropriations for R&D (government budget appropriations or outlays for research and development – GBAORD). The OECD database distinguishes between different types of funding: (1) direct funding, which includes allocations for R&D that is primarily devoted to the protection and improvement of human health; (2) funding for the advancement of knowledge, which, in the health sector, includes general university research funds expended on medical sciences, as well as non-oriented research; (3) other types of health funding, which are derived from OECD estimates based on national sources. These refer to the funding of R&D in hospitals and related sectors that are not recorded by GBAORD.

165 According to BMBF figures, direct funding in Germany amounted to EUR 1.3 billion in 2012. This included both the funding of R&D projects in the health sector – financed e.g. by the DFG or the BMBF – as well as institutional funding of major non-university research facilities. In the same year, EUR 2.8 billion was allocated to the advancement of knowledge in the area of health. From among this, the lion's share of EUR 2.5 billion was financed by general funds of universities.

166 The surveyed countries differ considerably with regard to the make-up of their state budget appropriations for health-related R&D. In Germany, health-related direct funding resources are lower than those allocated to the advancement of knowledge. In Sweden, direct funding accounts for only a small proportion of the total resources allocated, while e.g. in the US, the vast majority of resources is attributable to direct funding. In 2010, the United States' federal budget appropriations for health-related R&D amounted to USD 30.9 billion (cf. http://www.nsf.gov/statistics/seind12/append/c4/at04-28.pdf (last accessed on 10 January 2014); in 2009, federal budget appropriations for R&D in medical sciences allocated to academic institutions amounted to USD11.1 billion (cf. http://www.nsf.gov/statistics/seind12/append/c5/at05-07.pdf, last accessed on 10 January 2014).

167 These include e.g. revenue from publications, expert reports and lectures, as well as licencing and patent income.

168 Cf. in more detail http://www.dimdi.de/static/de/klassi/icd-10-gm/anwendung/zweck/g-drg/ (last accessed on 10 January 2014).

169 Cf. Statistisches Bundesamt, *Fachserie 11 Reihe 4.3.2*.

170 Cf. Statistisches Bundesamt, *Fachserie 11 Reihe 4.3.2*.

171 Cf. Statistisches Bundesamt, *Fachserie 11 Reihe 4.3.2*.

172 In this regard and in the following, cf. Statistisches Bundesamt, *Fachserie 11 Reihe 4.3.2.*, as well as Loos et al. (2014).

173 With regard to the year 2013, The University Chancellors' Working Group on University Medicine (Kanzlerarbeitskreis Hochschulmedizin 2013) anticipates a negative annual result for nearly half of the university hospitals.

174 Cf. in the following Albrecht et al. (2013).

175 Cf. in the following Leonhard (2005: 100f.), quoted in Loos et al. (2014).

176 Kanzlerarbeitskreis Hochschulmedizin (2013).

177 Cf. Loos et al. (2014) and Fischer (2013), quoted in Loos et al. (2014).

178 Cf. in the following CDU, CSU and SPD (2013: 80).

179 Cf. Wissenschaftlicher Beirat der Bundesärztekammer (2013) and http://www.uniklinika.de/media/file/4790.13-09_KMI.pdf (last accessed on 10 January 2014).

180 Information provided by GKV Spitzenverband.

181 Cf. Deutsche Hochschulmedizin e.V. (2013). Cf. Wissenschaftlicher Beirat der Bundesärztekammer (2013), http://www.uniklinika.de/media/file/4790.13-09_KMI.pdf (last accessed on 10 January 2014), Albrecht et al. (2013).

182 Cf. http://www.uniklinika.de/media/file/4790.13-09_KMI.pdf, Albrecht et al. (2013), DGIM (2013), Kanzlerarbeitskreis Hochschulmedizin (2013).

183 Cf. Albrecht et al. (2013).

184 In this regard and in the following, cf. Wissenschaftlicher Beirat der Bundesärztekammer (2013), as well as Loos et al. (2014).

185 In contrast to this, the subsidisation of research through revenues from healthcare is an established approach in the United States and Canada (cf. Loos et al. 2014).

186 Cf. in the following http://clinicaltrials.gov/ct2/about-studies/learn (last accessed on 10 January 2014).

187 Cf. Adler and von dem Knesebeck (2013).

188 Between 2003 and 2011, a support measure was jointly tendered by the BMBF and the DFG on an annual basis; this joint measure expired in 2012 and was replaced by two separate but coordinated measures (information by BMBF).

189 In addition to the measures outlined in Box 5, the BMBF granted start-up funding to medical faculties of tertiary education institutions, medical academies and non-university research organisations in the new federal states and also provided support to the Interdisciplinary Centres for Clinical Research (IZKF). The BMBF allocated a total of EUR 150 million in start-up funding for medical research in Eastern Germany. The second funding phase (1995 – 2001) was focussed on establishing structures for clinical research at faculty levels. Between 1995 and 2004, the BMBF supported eight IZKF centres, which had been selected via a competitive procedure. First and foremost, these centres were to establish efficient structures for clinical research across disciplines, develop an interdisciplinary research profile and promote young scientists. The funding volume amounted to EUR 92 million. A previous evaluation of the IZKF centres confirmed the support measure's strengthening effect on clinical research.Cf. http://www.gesundheitsforschung-bmbf.de/de/590.php (last accessed on 10 January 2014), Bührer et al. (2004), http://www.gesundheitsforschung-bmbf.de/de/165.php (last accessed on 10 January 2014), http://www.gesundheitsforschung-bmbf.de/de/463.php (last accessed on 10 January 2014).

190 Cf. in the following http://www.bmbf.de/de/1173.php (last accessed on 10 January 2014).

191 Between 2002 and 2008, the BMBF funded the creation of the expert network PAED-Net to the tune of EUR 5.4 million (cf. http://www.gesundheitsforschung-bmbf.de/de/465.php, last accessed on

10 January 2014). The PAED-Net facilities are located at six university hospitals. In collaboration with other partners, these facilities perform tests of medications on children to account for the metabolism of children during various developmental stages, which differs from that of adults. The expert network CHIR-Net and the Study Centre of the German Surgical Society (SDGC) are currently creating a professional infrastructure for surgical studies, while also supporting further training for surgeons in the area of clinical trial research and clinical trials on surgical issues (cf. http://www.bmbf.de/de/1173.php, http://www.klinikum.uni-heidelberg.de/Home.6187.0.html, http://www.chir-net.de/regionalzentren/heidelberg/, http://www.klinikum.uni-heidelberg.de/fileadmin/Chirurgie/sdgc/Home/100929_SDGC_FLyer.pdf, each last accessed on 10 January 2014). The BMBF has been providing the CHIR-Net with funding since 2005, which also included the support of the SDGC, which is co-financed by industrial partners. The SDGC also serves as the coordination office for CHIR-Net. Today, CHIR-Net comprises eight regional centres. In the first funding phase, the funding volume amounted to EUR 4.9 million and is currently being continued with a second funding phase, with a volume amounting to EUR 5.4 million until March 2014. The advancement of the German Clinical Trials Register (DRKS) was supported by the BMBF with EUR 2.3 million in the first funding phase (2007 – 2012) and with EUR 1.5 million in the second funding phase (2013–2016) (cf. http://www.gesundheitsforschung- bmbf.de/de/1869.php, http://www.gesundheitsforschung-bmbf.de/de/465.php, each last accessed on 10 January 2014). A comprehensive, publicly accessible register of planned, current and completed studies in Germany is thought to increase transparency in the area of clinical research.

192 Cf. in the following http://www.gesundheitsforschung-bmbf.de/de/4302.php (last accessed on 10 January 2014), http://www.bmbf.de/de/1173.php (last accessed on 10 January 2014).

193 Cf. http://www.gesundheitsforschung-bmbf.de/de/4302.php (last accessed on 10 January 2014) and http://www.bmbf.de/de/1173.php (last accessed on 10 January 2014).

194 Cf. http://www.gesundheitsforschung-bmbf.de/de/159.php (last accessed on 10 January 2014), BMBF (2006b), BMBF (2009a), http://www.kompetenznetze-medizin.de/Home.aspx (last accessed on 10 January 2014).

195 In this regard and in the following, cf. Loos et al. (2014), as well as Loos et al. (2011).

196 Cf. Dr. Thielbeer Consulting (2012).

197 Cf. Dr. Thielbeer Consulting (2012).

198 Cf. Gehring et al. (2013).

199 http://www.ncbi.nlm.nih.gov/books/NBK50888/table/ch3.t1/?report=objectonly (last accessed on 10 January 2014).

200 Cf. Charles River Associates (2004: 77).

201 Cf. NAMSE (2013), http://www.irdirc.org/?page_id=34 (last accessed on 10 January 2014), http://www.gesundheitsforschung-bmbf.de/de/4767.php (last accessed on 10 January 2014), http://www.eurordis.org/de/content/warum-forschung-ueber-seltene-krankheiten-so-wichtig-ist (last accessed on 10 January 2014), http://ec.europa.eu/research/health/medical-research/rare-diseases/index_en.html (last accessed on 10 January 2014), and EURORDIS (2010).

202 Cf. NAMSE (2013). Cf. in the following http://www.bmbf.de/de/1109.php (last accessed on 10 January 2014), and BMBF (2010: 22).

203 A special form of pooling research resources can be found at the NIH Clinical Center located in Washington, DC. The NIH CC is the world's largest facility exclusively dedicated to clinical research (cf. http://cc.nih.gov/about/welcome.shtml, last accessed on 10 January 2014, presentation documents by John I. Gallin , M.D., Director, NIH Clinical Center). The NIH CC selects its own patients and even recruits them on a worldwide basis. All of the patients participate in clinical studies. The objective is to swiftly translate scientific observations and findings into new diagnostic, preventive and therapeutic approaches to diseases. One of the NIH CC's focus areas is research into rare diseases, and the centre is designed in a way that is tailored to research requirements. Germany does not have such a facility, and such a facility would not suit the country's decentralised structures that are rooted in German history.

204 Cf. http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/main/h2020-wp1415-health_en.pdf (last accessed on 10 January 2014).

205 In this regard and in the following, cf. Loos et al. (2014), as well as Statistisches Bundesamt, *Fachserie 11, Reihe 4.5*. All figures refer to medical facilities and the universities' health sciences departments.

206 Cf. Regulation (EC) No. 141/2000 of the European Parliament and of the Council of 16 December 1999 on orphan medicinal products, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:018:0001:0005:en:PDF (last accessed on 10 January 2014). Cf. in the following NAMSE (2013).

207 Cf. http://www.fda.gov/regulatoryinformation/legislation/federalfooddrugandcosmeticactfdcact/significantamendmentstothefdcact/orphandrugact/default.htm (last accessed on 10 January 2014), http://europa.eu/legislation_summaries/internal_market/single_market_for_goods/pharmaceutical_and_cosmetic_products/l21167_de.htm (last accessed on 10 January 2014), vfa (2013a).

208 Cf. In the following NAMSE (2013), BMBF (2003), BMBF (2010: 22).

209 This is largely owing to the fact that the requirements for the approval of a substance have become stricter over time. This includes the proof of safety and effectiveness, tolerance and quality. Cf. Loos et al. (2014).

210 In this regard, cf. Loos et al. (2014), as well as vfa (2013b). Stakeholders from university medicine argue that the calculation of clinical trial costs has often been underestimated in the past due to the lack of necessary data, and that this shortfall had only been revealed with the gradual introduction of calculation of costs and separate accounting in university medicine. However, it has also been pointed out that the current state of implementation in the calculation of costs and separate accounting does not yet provide for a comprehensive, uniform calculation of overhead costs for clinical trials. The Association of Research-Based Pharmaceutical Companies (vfa) argues that calls for higher rates would jeopardise the competitiveness of Germany as a research location. The vfa disapproves of the reimbursement of overhead costs via a flat rate without any proven reference to the actual costs incurred by a specific study. The vfa further argues that payments that go beyond the reimbursement of expenses may suggest potential corruption. The vfa also rejects the idea of entering into contracts with individual stakeholders from university medicine such as laboratories or pharmacies in addition to the main contractor.

211 Cf. in the following Loos et al. (2014).

212 Cf. in more detail Loos et al. (2014).

213 Cf. e.g. Maier-Borst (2012).

214 Cf. EFI (2012: 54f.)

215 University medicine is subjected to specific rules and regulations that do not apply to other science segments: thus, §§ 1a, 2 and 2a, paragraph 1 No. 2 of the German Patent Act largely restrict patentability for large areas of university medicine. Cf. Loos et al. (2014: 145).

216 Cf. http://www.pfizer.de/medien/meldungen/meldung/news/pfizer-und-universitaet-giessen-bauen-strategische-partnerschaft-zur-entwicklung-von-therapien-gegen.htm, http://www.cpc-munich.org/infos-cpc/neues-aus-dem-cpc/news/article/13879/index.html, http://www.cpc-munich.org/infos-cpc/partner/index.html, http://www.abbott.de/press/show/e7340/e19695/e19264/index_de.html, http://www.uni-ulm.de/med/fakultaet/forschung/biu.html, http://www.charite.de/charite/presse/pressemitteilungen/artikel/detail/neuartige_forschungskooperation_von_charite_und_sanofi_aventis/, http://www.charite.de/charite/presse/pressemitteilungen/artikel/detail/neuartige_forschungskooperation_von_charite_und_sanofi_aventis/, http://www.charite.de/charite/presse/pressemitteilungen/artikel/detail/charite_und_sanofi_erweitern_ihre_partnerschaft_um_eine_diabetes_allianz/ (each last accessed on 10 January 2014).

217 On the reform of the Act on Employees Invention *(ArbnErfG)* and the associated abolition of the university teachers' privilege in 2002, cf. Cuntz et al. (2012).

218 In the view of the Expert Commission, grace period regulations should be designed in a way that alleviates the conflict between academic publishing and patenting. The respective regulations should

also aim to involve minimum efforts in examining patent applications. However, the grace period provision in US patent legislation, which has been revised recently, seems to place an emphasis on other strategic objectives. Cf. http://www.epo.org/modules/epoweb/acdocument/epoweb2/60/en/CA-106-12_en.pdf (last accessed on 10 January 2014). A one-to-one adoption of the United States' approach is therefore not recommended. At this point in time, it is still necessary to further investigate the optimal design of a grace period provision. What is more, the grace period has become an important element in the negotiations on a potential transatlantic free trade agreement between Europe and the United States.

219 The data collected as part of the *Gründungsradar* study by the Donors' Association for the Promotion of Sciences and Humanities in Germany show that the subject group medicine/healthcare at German universities only marginally provides for development and training in the field of entrepreneurship.

220 Cf. Kneller (2010).

221 Cf. EFI (2012: 76).

222 Cf. CDU, CSU and SPD (2013: 22, 140f.).

223 Cf. e.g. TMF (2014).

224 Telephone interview with Dr. Johannes Drepper (member of academic staff of TMF –Technology, Methods, and Infrastructure for Networked Medical Research coordination office) and Sebastian Mate (member of academic staff at the Department of Medical Informatics at Friedrich-Alexander-Universität Erlangen-Nürnberg).

225 Telephone interview with Sebastian Mate, member of academic staff, Department of Medical Informatics at Friedrich-Alexander-Universität Erlangen-Nürnberg.

226 Cf. https://www.i2b2.org/work/i2b2_installations.html (last accessed on 10 January 2014). Assisted by TMF, a German-language user group has been created in 2009. In March 2013, the University Hospital of Erlangen hosted the 1. European i2b2 Academic User Meeting (cf. http://www.pg-ss.imi.uni-erlangen.de/Seiten/FirstEuropeani2b2Workshop.aspx (last accessed on 10 January 2014).

227 The project is called Integrated Data Repository Toolkit (DRT1 and IDRT2). Cf. http://www.tmf-ev.de/Themen/Projekte/V091_IDRT.aspx (last accessed on 10 January 2014).

228 The project is called Electronic Health Records for Clinical Research (IMI-EHR4CR.) Cf. http://www.ehr4cr.eu/index.cfm (last accessed on 10 January 2014). The 1. European i2b2 Academic User Meeting was held in March 2013 at the University Hospital of Erlangen.

229 Examples include the following: the support measure "German Network for Bioinformatics Infrastructure" is dedicated to the development of several service centres with the corresponding infrastructure, which shall provide bioinformatics services. The measure aims to increase, improve and secure the availability of hardware, data resources and bioinformatics tools in the area of life sciences on a sustainable basis (cf. http://www.bmbf.de/foerderungen/22291.php, last accessed on 10 January 2014). As part of the research and funding concept "e:Med: Paving the way for the establishment of systems medicine", the measure "Demonstrators for an individualised medicine" supports projects that aim to show how data sets from high-throughput research can directly enhance individualised medicine (cf. http://www.bmbf.de/foerderungen/21800.php, last accessed on 10 January 2014). Within the framework of "ICT 2020 – Research for Innovation", the BMBF also provides funding for open-topic research projects in the area of "Management and analysis of large amounts of data (big data)" Cf. http://www.bmbf.de/foerderungen/21340.php (last accessed on 10 January 2014).

230 Putz (2011).

231 Thus, it is often the case that medical students start writing their doctoral thesis during the course of their studies, cf. Wissenschaftsrat (2002: 5). It is also worth noting here the shrinking number of students who aim for an experimental doctoral thesis that would meet high academic standards. This decline has been explained on the grounds that the curriculum for medical students has become more streamlined and regimented, making it difficult to integrate an experimental doctoral thesis.

Thus, it has been argued that medical training in Germany does not provide sufficient leeway. Cf. DGIM (2012).

232 Cf. Loos et al. (2014: 199).

233 Cf. Loos et al. (2014: 181) for an overview of MD/PhD programmes at medical faculties in Germany.

234 Cf. in the following http://connects.catalyst.harvard.edu/Profiles/about/default.aspx (last accessed on 10 January 2014), http://connects.catalyst.harvard.edu/Profiles/about/default.aspx?tab=faq (last accessed on 10 January 2014), http://connects.catalyst.harvard.edu/Profiles/about/default.aspx?tab=open (last accessed on 10 January 2014), http://connects.catalyst.harvard.edu/Profiles/about/default.aspx?tab=data (last accessed on 10 January 2014).

235 Cf. in the following http://catalyst.harvard.edu/news/news.html?p=1025 (last accessed on 10 January 2014), http://catalyst.harvard.edu/spotlights/eagle-i.html (last accessed on 10 January 2014).

236 Cf. in the following http://www.academia.edu/3470049/Ein_Semantic-Web-Ansatz_zum_Mapping_klinischer_Metadaten_am_Beispiel_eines_Bioproben-_Projektvermittlungs-Portals_fur_das_DPKK_auf_der_Basis_von_i2b2 (last accessed on 10 January 2014), https://www.i2b2.org/index.html (last accessed on 10 January 2014), https://www.i2b2.org/work/i2b2_installations.html (last accessed on 10 January 2014), ,http://www.ncbcs.org/index.html (last accessed on 10 January 2014), http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1839563/ (last accessed on 10 January 2014).), http://www.egms.de/static/en/meetings/gmds2009/09gmds337.shtml (last accessed on 10 January 2014).

237 Cf. in the following http://catalyst.harvard.edu/services/shrine/, McMurry et al. (2013), http://catalyst.harvard.edu/spotlights/shrine.html (last accessed on 10 January 2014), http://catalyst.harvard.edu/services/shrine/pilot.html (last accessed on 10 January 2014), https://open.med.harvard.edu/display/SHRINE/About (last accessed on 10 January 2014).

238 The project is called Electronic Health Records for Clinical Research (IMI-EHR4CR), cf. http://www.ehr4cr.eu/index.cfm (last accessed on 10 January 2014).

239 Cf. http://bd2k.nih.gov/ (last accessed on 10 January 2014), BITKOM (2013).

240 Admission requirements vary according to faculty. Overall, these programmes have a competitive design due to the limited number of participants. Cf. Loos et al. (2014: 180).

241 Cf. Gerst and Hibbeler (2012). The importance of a post-doctoral degree in the medical field is reflected in the high rate of post-doctoral degrees awarded and in the growing absolute number of post-doctoral theses. While the post-doctoral rate and the number of registered post-doctoral theses have been declining across all subject groups since 2004, the number of post-doctoral theses in the subject group medicine/health sciences has increased in the same period. Today, one out of two post-doctoral degrees is awarded in the medical domain. Furthermore, from among all subject groups, medicine/health sciences records the second highest rate of post-doctoral degrees awarded (11 percent), just after the subject group language and cultural studies (13 percent). Cf. Konsortium Bundesbericht wissenschaftlicher Nachwuchs (2013: 30). Cf. also interview with Prof. Dr. Friedrich Luft from 5 November 2013.

242 Interview with Dr. Daniela Krause on 22 November 2013.

243 Both the Expert Commission and the German Council of Science and Humanities in Germany have repeatedly called for greater differentiation in the higher education sector. Cf. EFI (2012: 72) und EFI (2013: 22). Cf. Wissenschaftsrat (2010: 9f.).

244 Cf. Luft (2013: 18f.).

245 Cf. Loos et al. (2014: 193). Cf. EFI (2012: 51).

246 Cf. Luft (2013).

247 Cf. Loos et al. (2014: 186).

248 Wissenschaftsrat (2004: 72).

249 Fulda (2012).

250 While university hospital physicians "predominantly active in patient care" are remunerated according to the Collective Agreement for Physicians at University Hospitals (TV-Ärzte), physicians predominantly active in research are remunerated according to the Public Sector Collective Agreement on *Länder (TV-Länder)*, which is far less attractive. Cf. Loos et al. (2014: 186).

251 While the division of research activities and patient care would be possible in principle, it is poorly implemented in practice. IGES workshop on 10 September 2013.

252 In the United States there are three career models, each with a specific division of time: – clinical care and teaching (50 percent patient care and 50 percent teaching);– clinical care and clinical research (80 percent patient care and 20 percent research); – basic research (20 percent patient care and 80 percent research). Regulations may vary in practice.

253 If a physician is financed via acquired research funds (grants), strict rules are applied to the maximum time the physician may spend on clinical work. In the first two years of a grant, strictly no more than 25 percent may be dedicated to clinical work. If the physician is funded via several grants, he or she must indicate the percentage of time spent on specific projects. Interview with Dr. Daniela Krause on 6 November 2013.

254 Cf. Fulda (2012), Gerst and Hibbeler (2012), as well as Haverich (2008: 4).

255 Cf. EFI (2011: 18ff.) and EFI (2012: 88ff.).

256 Physicians predominantly active in research are usually paid according to the Public Sector Collective Agreement on *Länder (TV-Länder)*. Physicians active in patient care are covered by the Collective Agreement for Physicians at University Hospitals (TV-Ärzte). The pay gap is considerable: a physician who is paid according to *TV-Länder* (salary group 14), receives EUR 4,051 per month after one year (EUR 4,285 from the third year). A physician who is paid according to TV-Ärzte (salary group Ä2, specialist) receives EUR 5,570 after one year (EUR 6,036 from the fourth year), cf. GEW (2013) and Marburger Bund (2013).

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257 Inward and outward migration refer to long-term employment in another country and does not include short, temporary stays as a visiting scientist or outbound trips in the context of congresses or international cooperation projects. In this regard, cf. also Noorden (2012: 326), who differentiates between long-term relocations and short-term visits ("sabbaticals or fortnight-long trips that allow scientists to build research networks without actually settling in another country").

258 The quality of scientists is often measured on the basis of the impact factor (see Box 9). Yet, there are many more dimensions of a scientist's quality, and these can only partially be captured by the impact factor. Despite these constraints, the impact factor continues to be the most widely used measurement concept, which shall also be employed later in this chapter for operationalising the quality of scientists.

259 Yet, inventors with German origins were ranked among the largest group of high-tech entrepreneurs in the United States. A disproportionately high number of inventors relocate to other countries and successfully translate their ideas into market innovations and also benefit from better conditions for start-ups in the United States.

260 Cf. OECD (2013b).

261 The analysis includes all scientists with at least two academic publications in the database, whereby it could be determined whether the respective publications had been recorded in the same country or in another country. If the country of an author remains the same for two publications, the scientist is considered a "stayer". If the country changes, the scientist is then considered to be a "mover". For researchers with at least three publications, "movers" can be further divided into "returnees", i.e. those who return to a country that they had previously worked in, and "new inflows", i.e. those who have moved to a country for the first time.

262 It should be noted that these figures are (gross) flows, i.e. the number of arrivals over the period under review; an analysis of the foreign workforce stocks at a given point in time might reveal quite a different picture. The Federal Office for Migration and Refugees (BAMF 2013a: 21ff.) provides an overview of the stock of foreign scientists at German research institutions in 2011. Among other things it could be shown that from among the total of 300,000 scientists at German tertiary

education institutions approx. 10.5 percent are scientists from abroad. The proportion is significantly higher at the Max Planck Institutes: 25 percent of its 6,777 scientific staff do not hold German citizenship (13 percent from EU-27 countries). The Helmholtz Association (14,700 scientists) is ranked in the middle field, with 17 percent of foreign scientists (8.3 percent from EU-27 countries). The Leibniz Association (6,500 scientists) is also ranked in the middle field, with 12.3 percent of foreign scientists (4 percent from EU-27 countries), and so is the Fraunhofer-Gesellschaft (9,900 scientists) with 8 percent of foreign scientists. Data on foreign scientists are not available for other non-university research organisations, research-orientated companies, federal department research institutions and other contract research institutions.

263 Based on data from a survey among scientists in the fields of biology, chemistry, materials and earth and environmental sciences, Franzoni et al. (2012a) show that the share of German scientists with international study and work experience ranks in the upper middle field among competitor countries (58 percent); only Australia, Canada, India, Spain and Switzerland have a higher share. However, the returnee rate among Germans is only in the lower third in an international comparison. Swiss scientists show a similar returnee rate (57.8 percent), while e.g. the returnee rate in Australia (70.8 percent), Canada (64.4 percent) and Spain (86.7 percent) is significantly higher. Belgium, Italy, the Netherlands and Great Britain display a lower returnee rate (between 50 and 60 percent), and India displays the lowest returnee rate (47.1 percent) (cf. Franzoni et al 2012a: 1250, table 1).

264 However, the share of scientist inflows differs considerably when considering internationally renowned US universities rather than the US science system on average. The United States' top universities typically have a much higher share of internationally mobile researchers. While there are no official data available on the share of internationally mobile scientists at top research institutions in the US, there are clear indications of a higher proportion of mobile scientists compared to the national average: thus, between 1990 and 2000, more than one quarter of the Nobel Laureates from the United States – which almost exclusively draw from these institutions – were first-generation immigrants. What is more, about three quarters of all inventions from the universities of California, Stanford, and the MIT in 2011 involved at least one foreign scientist (cf. The Partnership for a New American Economy, 2012).

265 Cf. OECD (2013b).

266 Cf. Neuhäusler et al. (2014).

267 In the below analysis, international mobility of patenting inventors is either measured according to a change in the inventor's place of residence – as indicated in the patent document (Neuhäusler et al. 2014) – or according to differences between an inventor's nationality and place of residence (WIPO 2013) based on the information disclosed by the inventor or, up until 2012, based on the mandatory disclosure in the patent application process as part of the Patent Cooperation Treaty (PCT) procedure. Where the descriptive analysis of data allows, patenting of mobile inventors is subdivided according to technological fields and the size of applicant firms. Patent statistics are a useful supplement to bibliometric data and micro-census data as they do not require a prior definition of the qualification level and the academic context. Another advantage of patent statistics is the fact that the selected group is particularly relevant to innovation, i.e. patent exploiters and inventors of technical knowledge from industry and academia.

268 For a more detailed discussion, cf. OECD (2013b: 2).

269 Cf. Wissenschaftsrat (2013c).

270 Cf. BAMF (2013a).

271 This may be due to the small size of the country, which has the initial effect that mobile scientists are more likely to go abroad when changing jobs, i.e. there might be a broader basis for returnees. Yet, it can be assumed that the high rate of returnees cannot be explained solely with this size-related effect, especially when considering the relatively low returnee rate of e.g. Austria.

272 SNIP stands for "source-normalised impact per paper". This means that the citation impact is measured for each of the journals included in the Scopus database. SNIP is defined as the quotient of two indicators: "average citation count per paper in a specific journal" and "average citation potential

in the journal's subject field". The scientific impact of an author (or the impact of his/her mobility) equals the median impact of publications/journals of this author. The quality of the journal is thus used as a proxy for the quality of a publication and its author.

273 The gap between stayers and movers is particularly pronounced in Italy, Spain, Chile, India, China and Russia (cf. Figure 22).

274 However, outflowing scientists are not necessarily US citizens; they might be scientists who once published in the United States in their academic career. This includes e.g. graduate students from Europe who had come to the United States for their doctoral thesis, i.e. they released their first publication in the US and then went back to their country of origin or to a third country for further publications. In the respective target country, they might belong to the above-average group scientists, even though they might have belonged to the below-average group when still in the US.

275 A study by Parey and Waldinger (2011) on the effects of the Erasmus programme also shows that, for German students, studying abroad greatly increases the probability of subsequent employment abroad. Most frequently, employment is taken up in the very country in which the study had been previously completed (cf. Parey and Waldinger 2011: 26).

276 Based on citation analyses for nanotechnology, Walsh (2013) shows that especially (highly cited) top scientists from Germany migrate to the United States. A study by Franzoni et al. (2012a) confirms that the United States are the top target country for German natural scientists – 22 percent of all German natural scientists abroad can be found in the US – followed by Switzerland (19 percent) and Great Britain (18 percent). In fact, the United States are the main target country for all natural scientists, and not German scientists alone (cf. Franzoni et al 2012a: 1250, table 1).

277 Cf. Franzoni et al. (2012a: 1250, table 1).

278 Cf. Franzoni et al. (2012a: 1250, table 1).

279 Cf. Franzoni et al. (2012a: 1250, table 1).

280 Figures according to BMBF as presented in a ministerial meeting, as well as Statistisches Bundesamt (2012b).

281 Cf. iFQ (2008a). Figures on the share of foreign scientists in 2008 are not available for the Future Concepts funding line.

282 Figures according to BMBF as presented in a ministerial meeting. The majority of scientists are from Europe (15 percent), North America (11 percent) and Asia (almost 7 percent). Cf. Wissenschaftsrat (2013c).

283 Cf. iFQ (2008b).

284 Cf. Enders and Mugabushaka (2004), as well as Sauer and Ette (2007).

285 Cf. Wissenschaftsrat (2013c).

286 A recent report by the Federal Office for Migration and Refugees (BAMF 2013a), provides a comprehensive analysis of the stock of foreign scientists in Germany. Similarly, the report is based on data from the micro-census, but also assesses statistics provided by DAAD, HIS and W. Bertelsmann Verlag (wbv) in order to account for foreign scientists at German universities. While the overall picture still remains incomplete, the report further illustrates e.g. that China, Italy and Austria are the main countries of origin for foreign academic staff in Germany.

287 The findings presented here are based on an empirical study on employment of foreign scientists in Germany (micro-census data), and a study on employment of scientists in the United States based on comparable data from the American Community Survey (cf. Cordes and Schiller 2014). Since the data sources and the respective variables are comparable, it is possible to conduct an indirect comparison of migration patterns in Germany and the United States. Cordes and Schiller (2014) restrict their analysis to gainfully employed persons and migrants who acquired their qualifications immediately prior to the year of their immigration, with the aim of gaining a more precise indicator for human capital acquired from abroad and attracted to the German labour market.

288 The type of occupation, industry affiliation or the qualification level (academics and PhD graduates in particular) can also be used to categorise the data. For instance, the qualification structure of foreign employees shows that the structure is much more polarised than that of German employees.

For some of the countries of origin, the share of university graduates is considerably higher than it is among German natives (e.g. in the US or in France). At the same time, there are a multitude of countries of origin for which the share of university graduates is much lower, while the share of unskilled workers (i.e. workers without vocational qualifications) is much higher. For instance, 74 percent of the workforce with Turkish citizenship have no vocational qualifications, whereas only 15 percent of German workers are lacking vocational qualifications. Cf. Cordes and Schiller (2014: 17).

289 It should be noted, however, that foreign citizenship and employment in Germany are not necessarily accompanied by mobility, just as German nationality does not necessarily rule out mobility. Thus, citizenship as an indicator provides a somewhat blurred picture of the international mobility of scientists and the countries that invested in their training (Cordes and Schiller 2014: 15). That said, the share of immigrants among foreign nationals actually amounts to approximately 80 percent and is thus relatively high, i.e. in the vast majority of cases mobility is actually recorded (Cordes and Schiller 2014: 15).

290 Cf. Cordes and Schiller (2014: 28).

291 This also applies to EEA nationals and their families. Exceptions include Romania and Bulgaria: up until 31/12/2013, citizens from these countries could take up employment in Germany only with prior approval by the Federal Employment Agency (unless applicants had a higher education degree); albeit with priority towards third countries (cf. BAMF 2013a: 19). As of 01/01/2012, individuals with a higher education degree do not require a work permit for skilled employment.

292 The current rise in overall immigration to Germany from 278,000 in 2011 to 389,000 in 2012 is largely driven by the euro crisis and the increased freedom of movement within the EU. Bertoli et al. (2013) assume that these two short-term factors account for up to 78 percent of the current growth in immigration. Cf. in more detail BAMF (2013b: 16ff).

293 Cf. BAMF (2013a: 18).

294 Cf. BAMF (2013a: 41).

295 Cf. BAMF (2013a: 44).

296 Cf. BAMF (2013a: 43).

297 Cf. BAMF (2013a: 43).

298 Cf. BAMF (2013a: 19).

299 Cf. BAMF (2013a: 19).

300 Cf. BAMF (2013a: 19).

301 The number of scientists appears to be much smaller then. In total, only 780,000 economically active persons work in research-related industry sectors. Based on this definition, the share of immigrants is considerably higher (9.1 percent), but still smaller than in the rest of the economy (10.6 percent) (Cordes and Schiller 2014, table 7–3). It is striking that the proportion of foreigners is especially low (6.2 percent) in the higher education sector, while it is significantly higher in R&D services (9.9 percent). The proportion of immigrants in the research sector declined sharply between 2009 and 2010, which in turn was largely due to a significant decline of immigrants in the higher education sector (Cordes and Schiller 2014, figure 3 – 8).

302 It can be confirmed that those moving from Germany to the United States include highly skilled individuals in particular, while this effect is much less pronounced with regard to employees from Great Britain or Canada. The smaller share of university graduates among Canadians and Britons in the US might be partially attributable to the fact that language barriers represent a lower threshold for Canadian or British workers with lower qualifications (due to their mother tongue being English). This may account for the relatively high number of Canadian and British workers with low qualifications, as it is easier for them to migrate than it is for German workers with low qualifications. Overall, the mobility patterns of scientists employed in the US confirm the patterns derived from the bibliometric data: Great Britain and Canada display a similar scientist mobility structure as the United States (with a positive selection by mobile scientists that improves the knowledge pool).

303 The high share of doctorate graduates among gainfully employed Germans in the United States is quite striking – also in comparison with other nationalities: thus, e.g. British employees in the United States have only a 7.9 share of doctorate graduates, and Canadian employees have a mere 6.5 share of doctorate graduates. With a 14.0 percentage share, France has a similar level to that of Germany, and the same can be said for Central Europe with a percentage share of 14.3 percent.

304 In the 1990s, an average of 100 scientists newly arrived in Germany per year. This rate increased in the early 2000s to around 300 per year, reaching a level of approximately 400 in 2008, which is roughly the same level as that of Great Britain – albeit Great Britain has recorded a decreasing trend since the 2000s (cf. Cordes and Schiller 2014: 39ff.).

305 Since the confidence intervals of population estimates are larger in the case of small sample sizes, any downward deviations in the shares reported for Germans in the population may also be more pronounced. Yet, even when taking into account estimation errors, the shares of university graduates and doctorate graduates are still considerably higher among Germans than it is among US citizens (cf. Cordes and Schiller 2014: 37, table 4–2).

306 A similarly high share of university teachers is recorded e.g. for immigrants from France (5.8 percent) and Central European countries excluding Great Britain (6.0 percent), while immigrants from Great Britain (3.1 percent) and Canada (3.5 percent) once again display a fairly low rate (cf. Cordes and Schiller 2014: 51, figure 4–4).

307 At the same time it can be observed that a large share of gainfully employed Indian citizens in the United States work in mathematical and IT professions (cf. Cordes and Schiller 2014: 51, figure 4–4), accounting for 16.5 percent of all economically active Indian citizens in the United States. If this occupational group were excluded, the specialisation of Indian immigrants would be approximately in the middle field of the remaining countries of origin.

308 Cf. Rashidi and Pyka (2013); Nathan (2013).

309 Cf. Hunt and Gauthier-Loiselle (2010).

310 According to this, a 1 percent increase in the share of foreign college graduates increases a federal state's patents per capita by 9 to 18 percent.

311 Cf. Niebuhr (2010); Audretsch et al. (2010).

312 Mobile inventors are only identified as such if the inventor, according to the study of Neuhäusler et al. (2014) a) filed a patent in the base year of 2000 and also filed a patent after he/she moved to another country during the period under review, and, according to the study of Neuhäusler et al. (2014) and WIPO (2013) b) if the inventor filed the patent application with several patent offices ("transnational patent") – a procedure that is more cost-intensive than a national patent application – or, alternatively, via the PCT route. Based on these criteria, the focus here is on mobile inventors with high quality patents.

313 Also within Germany, SMEs are losing considerable knowledge through inflows and outflows of inventors, as SMEs are more likely to be affected by the mobility of patenting staff. The biggest winners in this regard are usually knowledge-intensive companies (cf. Dorner et al. 2013).

314 Cf. Neuhäusler et al. (2014: 4).

315 Cf. WIPO (2013).

316 Cf. WIPO (2013).

317 The outflow rate is defined as the quotient of national inventors who live abroad ("diaspora") relative to the sum of the total of all domestic inventors (national and inflowing inventors, "residents") and the "diaspora".

318 Cf. WIPO (2013), own calculations. In comparison: typical destination countries for US inventors include the neighbouring country of Canada, as well as China and Germany (with just over 10 percent each).

319 Cf. Wadhwa et al. (2012).

320 In contrast, German immigrants in the United States – irrespective of their qualification and occupation – represent only the twelfth largest group of immigrants (cf. Cordes and Schiller 2014).

321 Cf. Wadhwa et al. (2012) and Müller et al. (2013: 17, figure 3).

322 Cf. Neuhäusler et al. (2014).

323 Cf. Neuhäusler et al. (2014: 7, figure 3).

324 Cf. Neuhäusler et al. (2014: 7, figure 3).

325 Cf. Neuhäusler et al. (2014). However, due to the available data, the distinction between extra-firm and intra-firm mobility is very fuzzy: based on the records, the occurrence of mergers and acquisitions suggests a change of company, even though the inventor merely moved within the same company. As a result, the scope of extra-firm mobility is generally overestimated, which means that extra-firm mobility identified via this record tends to display the upper bound of actual mobility between different companies. (It is of course also the case that the actual value of intra-firm mobility is underestimated, thus, estimates tend to display the lower bound).

326 Cf. Neuhäusler et al. (2014: 4). Double-counting may occur as data have not been adjusted for repeated mobility. According to the study, the majority of inventors patenting in Germany in 2000 and subsequently moved abroad filed their patent application together with a foreign patent applicant, mostly a foreign company. According to the applicants' residence details provided on the patent document in the year 2000, the share of these applications with foreign applicants amounts to almost 60 percent among all mobile inventors, i.e. German patent applicants account for less than 40 percent.

327 Cf. Neuhäusler et al. (2014: 10, figure 5). Compared to 2001, a significant decline in inventor outflows was recorded in 2009 e.g. in the fields of electronics (approx. –40 percent) and in lighting and electrical equipment (approx. –50 percent). Relative to all inventors in the respective technology field (p. 9, figure 4), the highest share of mobile inventors was recorded in the manufacture of electronic medical instruments (over 25 percent) and broadcasting and television technology (over 15 percent).

328 Cf. WIPO (2013).

329 The European countries show a rather mixed picture: Swedish and Swiss scientists, for instance, are very likely to leave their home country (40 percent and 19 percent, respectively). For French and Dutch patenting researchers, the figures are below the German level (7 percent and 10 percent, respectively). Cf. WIPO (2013), own calculations according to aggregate bilateral data by WIPO.

330 Again, research institutions in the United States (41 percent), Switzerland (17 percent) and Great Britain (13 percent) are the top destinations for German scientists active in patenting.

331 Germany attracts inflowing inventors active in patenting primarily from the bordering countries of Austria (10 percent), France (10 percent) or Great Britain (8 percent), while the United States primarily attract inventors from China (22 percent), India (18 percent), Canada (9 percent), as well as Great Britain (7 percent) and Germany (5 percent). Cf. WIPO (2013), own calculations according to aggregate bilateral data by WIPO.

332 Cf. Niebuhr (2010).

333 Cf. OECD (2008).

334 WIPO (2013), own calculations according to aggregate bilateral data by WIPO.

335 This is also the reason why Noorden (2012: 326) refers to the United States as "the number-one destination for expatriate scientists from almost every nation" – despite the fact that, proportionately, Switzerland and Canada, and certainly not the United States, are the top destinations.

336 Some of the latter countries and innovation locations also record a considerable turnover of mobile inventors that does not differ much from the German level when considering the size of the respective economies.

337 Conversely, and contrary to some suggestions, immigration may not only have positive effects. This is the case whenever migrant scientists displace domestic scientists and thereby do not contribute to increasing the knowledge pool and thus a country's scientific productivity or innovation. Yet, such displacement effects are not supported by empirical studies. However, studies on overall labour mobility (i.e. not just scientists) suggest that emigration has significant positive effects on scientists remaining in the country. Thus, Elsner (2012) states that Lithuania recorded a wage increase of 0.67 percent among stayers during a 1 percent increase in emigration.

338 Cf. Nathan (2013).

339 Cf. Nathan (2013: 10f.).

340 For economists in German-speaking countries, Bäker et al. (2013) show that stays abroad of at least six months are accompanied by positive productivity effects measured by the annual publication output. While they, too, suggest that this is partially owing to networking effects, they also consider this to be a (self-)selection effect in the sense that scientists with above-average productivity are more likely to go abroad or receive agency funding.

341 Similar negative effects caused by the loss of top scientists can be observed in institutions whenever scientist die unexpectedly at an early age. Thus, e.g. the publication productivity of co-authors sustainably decreases by 5 to 8 percent after the death of an "academic superstar" (cf. Azouly et al. 2010).

342 For a review of the relevant literature, cf. Nathan (2013).

343 Cf. Nathan (2013).

344 Positive effects from the inflow of staff have also been confirmed with regard to inventors who move between companies within a country (cf. Stoyanov and Zubanov 2012 for Denmark). However, Maliranta et al. (2009) detect a positive productivity effect only in cases where R&D staff move to formerly non-R&D areas. This suggests that mobile employees are able to implement their knowledge in their new role without substantial new R&D efforts.

345 Cf. Nathan (2013: 20) or Kerr and Lincoln (2010). The latter have examined the influence of increased inflows of scientists and engineers in the United States based on the H-1B work visa, which is the counterpart of the German residence permit according to § 18,4. The H-1B visa permits a three-year stay in the United States for highly qualified foreign workers.

346 Cf. Hunt and Gauthier-Loiselle (2010).

347 Cf. Noorden (2012). However, this does not necessarily imply that these individuals would also be among the most-cited if they were in their home country; i.e. from a global perspective, these migration patterns can be highly efficient.

348 Cf. Waldinger (2012b).

349 Cf. European Research Council (2012).

350 Cf. Waldinger (2010, 2012a).

351 Cf. OECD (2013b, figure 7).

352 Cf. WIPO (2013: 35).

353 Positive networking effects have also been confirmed with regard to company changes within a country. Cf. Kaiser et al. (2011) on Denmark.

354 However, Noorden (2012) suggests that the pattern of international exchange will change significantly in the future. He assumes that, in future, there will be a higher number of short stays ("repeated week- or month-long visits") that will also complement longer stays abroad. Noorden suspects that the idea of researchers moving permanently from one country to another is largely outdated and that it will become increasingly common for scientists to reside in one country and work in several additional countries for a period of several weeks or months.

355 Cf. Noorden (2012: 329).

356 Cf. Janson et al. (2006). According to the authors, the higher stratification of the United States' higher education system is one of the main factors in explaining the attractiveness of the US system in comparison to Germany. Thus, the privileged treatment of the best young scientists is considered to be more attractive in the United States, while it seems to be more difficult to ascend to the group of privileged academics in Germany. The authors also clear up the stereotype according to which scientific career paths are faster in the US, careers between graduation and professorship are more selective in the US, income levels are lower in Germany, and German institutions provide more fixed-term and part-time contracts. In fact, Germany is rather similar to the United States with regard to all of these factors. According to the authors, one of the main differences is that the US system offers better prospects for permanent employment and promotion within one and the same institution when compared with the German system.

357 Cf. Franzoni et al. (2012a).

358 The study by Franzoni et al. (2012a) documents a survey among more than 15,000 scientists from 16 countries, conducted in 2011. The survey included scientists from four disciplines (biology, chemistry, materials and environmental sciences).

359 Conversely, a high number of articles has also been recorded e.g. for China. However, China's impact factor is far below average – which corresponds with the country's immigration rate, which is extremely low in international comparison.

360 Franzoni et al. (2012a).

361 Hunter et al. (2009) have found that physicists tend to move to countries that record high R&D expenditure levels.

362 Sjaastad (1962) as well as Grogger and Hanson (2011) have shown that differences in income are an important factor in international mobility.

363 According to a recent OECD publication (2013c), family reunification provisions for highly skilled workers and scientists are fairly generous in Germany when compared internationally, even for non-EU citizens. In Germany, the partner and family members of a highly qualified "principle person entitled" have equal rights with regard to residence and visa regulations. Furthermore, as per §§19 to 21 *AufenthG*, restrictions such as German language requirements for family members do not apply to highly qualified workers or Blue Card holders. In addition, this group of immigrants is also exempted from the age condition for both spouses (18 years).

364 In this context, relocation services might prove valuable. These assist academics and their families throughout the entire relocation process. Services include intercultural training and assistance in the procurement of accommodation, assistance with formal requirements, language courses, the selection of schools and assistance in creating new social environments.

365 Cf. https://www.kfw.de/PDF/KfW-Research/Economic-Research/Veranstaltungen-Vorträge/PDF-Dateien-Veranstaltungen-2013/Jonathan-Chaloff_100613.pdf (last accessed on 10 January 2014).

366 On the occasion of the GAIN conference, the network meeting of German academics in the United States, several participants underlined the importance of dual career issues – i.e. issues in integrating the partner into the workforce – in the German research system, and also identified the need for better salaries, long-term employment contracts, flat hierarchies and greater flexibility. Cf. DFG (2013b).

367 As in the past, such limited measures do not suffice to recover top scientists. Yet, these measures still lead to systematic improvements for Germany's knowledge pool: today, the average quality of returnees is much higher than the quality of stayers (cf. Figure 22).

368 Cf. Noorden (2012: 329).

369 Suitable measures include e.g. the abolition of priority reviews for understaffed professions (which has already been implemented), lower income thresholds, an improved information policy, explicit campaigning to attract higher education graduates, and enhanced efforts in creating a "welcoming culture"; cf. EFI (2012: Chapter B2).

370 Existing data collection efforts and evaluations e.g. by the BAMF (2013a) should be advanced and expanded. For instance, while data on the nationality of the researcher is collected, there is no information provided on the previous country of residence and the country in which the researcher obtained his/her qualification. Furthermore, the structure of data records does not allow for tracing long-term mobility flows across several countries. To achieve this, innovative data processing methods could be employed to collect information available online e.g. on the basis of CVs and other data available on the internet (natural language processing).

B 3

371 Figures by European Information Technology Observatory (EITO) for the year 2012.

372 Cf. BMWi (2012: 8f.).

373 In international literature, the ICT term "enabler" is often used when referring to follow-up innovations.

374 In this regard, cf. the studies by Atkinson and McKay (2007), McKinsey (2001, 2002), as well as Brynjolfsson and Saunders (2010).

375 Cf. Bresnahan and Trajtenberg (1995: 83f.), as well as Helpman (1998: 193ff.).
376 On the interrelationship between ICT and productivity gains, see Brynjoffsson and Saunders (2010, chapter 3), Oliner et al. (2007), as well as Byrne et al. (2013).
377 Cf. Jorgenson et al. (2006).
378 Atkinson and McKay (2007), and McKinsey (2002).
379 Cf. OECD (2005), Ark et al. (2010), as well as Atkinson and McKay (2007).
380 See www.euklems.net for an overview, as well as the most recent publication in Timmer et al. (2013).
381 In this regard, cf. earlier studies by Hempell (2002), as well as more recent studies by ZEW.
382 In this regard, cf. the respective analyses in the BMWi's Monitoring Report Digital Economy *(Monitoring-Report Digitale Wirtschaft)* (2012: 19ff).
383 Cf. BMWi (2012: 8f.). The differences between the Bitkom values and those from the BMWi's monitoring report are largely attributable to the inclusion of ICT trade and to differences in accounting for individual branches of electronics.
384 BMWi (2012: 15f.) as well as calculations by ZEW (2011).
385 Market data by European Information Technology Observatory (EITO 2013).
386 Cf. Gehrke et al. (2014: 18).
387 In this regard, cf. the study on software champions in Germany to be published shortly.
388 Cf. EITO (2013).
389 Cf. Gehrke et al (2014: 18).
390 This was primarily caused by large price reductions for ICT goods. Between 2005 and 2012, the market volume decreased by 0.4 percent annually in the United States, Japan and Europe. Cf. EITO (2013).
391 Wincor-Nixdorf, a fairly strong provider of cash management systems, may also serve as an example for the fact that hardware manufacturing has been largely outsourced to suppliers and relocated to locations abroad.
392 See the latest analysis on the 1,000 largest R&D-based companies by Booz & Company (2013).
393 Cf. Gehrke et al. (2014).
394 Cf. Gehrke et al. (2014).
395 A look at the specialisation index reveals that especially Korea, Sweden and France have emerged as countries with a strong focus on ICT. China and India are also very strong in this segment. Germany displays a negative specialisation index in ICT and has fallen in the ranking of ICT patent applications since 2000. Cf. Gehrke et al. (2014: 73ff.).
396 Cf. Gehrke et al. (2014)
397 Cf. Gehrke et al. (2014: 85).
398 Cf. Gehrke et al. (2014: 94).
399 Cf. Blind et al. (2011).
400 Cf. http://europa.eu/rapid/press-release_IP-13-971_en.htm (last accessed on 10 January 2014).
401 Cf. http://www.faz.net/frankfurter-allgemeine-zeitung/deutsche-gerichte-epizentrum-des-patent-konflikts-11717063.html und http://www.zdnet.de/88175490/mannheimer-gericht-setzt-patentklage-von-google-gegen-apple-aus (last accessed on 10 January 2014).
402 A comprehensive legal analysis on this topic has been provided by Picht (2013).
403 Cf. Cremers et al. (2013).
404 In September 2013, sixteen major technology companies published an open letter to the European Commission. The signatories of the letter welcomed the creation of a unified European patent system but also expressed the concern that the new system would enable "patent trolls" to become more active in Europe than had previously been the case. Cf. http://www.nytimes.com/2013/09/26/technology/tech-giants-fear-spread-of-patent-wars-to-europe.html?pagewanted=all&_r=0. (last accessed on 10 January 2014).
405 Cf. Pohlmann (2010).

406 In this regard, see the analysis of Funk (2009) on the shift of standard-setting activities in telecommunications towards Asia.

407 This was preceded by several programmes for the promotion of data processing, microelectronics and ICT applications first established in the 1970s.

408 BMBF (2007: 24).

409 For a detailed description of these ventures, cf. BMBF (2007: 28ff.).

410 BMBF (2007: 35ff.).

411 According to the ICT 2020 report of the BMBF (2007: 72), a total of EUR 3.22 billion was expended in the course of the five-year period between 2007 and 2011. Of this amount, EUR 1.74 billion was allocated to institutional funding and EUR 1.48 billion to ICT project funding. 60.5 percent of the BMBF's project funding volume for ICT went into public research, with the majority of funds directed at non-university organisations (estimates based on the BMBF funding catalogue database). Overall, approximately 80 percent of federal funds in the field of ICT are used for public research. Compared to Germany, the United States and Asian countries allocate a significantly lower proportion of ICT funds to public research institutions. In these countries, there is a heavier focus on direct or indirect funding of private R&D in the ICT sector.

412 Figures are based on data from the E-CORDA contract database (as of 25/10/2013), courtesy of the BMBF's EU office.

413 Cf. CDU, CSU and SPD (2013: 138-143). ICT in also mentioned in several other passages of the coalition agreement between CDU, CSU and SPD.

414 Cf. CDU, CSU and SPD (2013: 139).

415 The study by Falck et al. (2013) identifies key application areas in telecommunications in Germany. Although ICT comprises more than just telecommunications, the priority application areas identified by the authors equally apply to information technology.

416 According to estimates by the EU Commission, cloud computing could add nearly EUR 600 billion to EU GDP between 2015 and 2020.

417 This is one of the centrals calls expressed by the CDU Wirtschaftsrat (2013), the party's economic advisory council, and was also discussed at the European Cloud Partnership meeting in November 2013.

418 Cf. Statistisches Landesamt Baden-Württemberg (2012: 86ff.).

419 A study by TÜV-Rheinland and Dresden University of Technology on behalf of the BMWi examined different expansion scenarios with reference to business and economic considerations. The relevant estimates provide a solid basis for developing further measures.

B 4

420 Cf. Leszczensky et al. (2013, figure 7.14).

421 In this context, the term "diversity" is often used.

422 Cf. EFI (2013).

423 Cf. Hoogendoorn et al. (2013), Smith et al. (2006), and Herring (2009).

424 Cf. Deszö and Ross (2012).

425 Cf. Parotta et al. (2013), as well as Weber and Zulehner (2010).

426 Cf. European Commission (2013), Schiebinger and Schraudner (2011).

427 Cf. Statistisches Bundesamt (2012c), *Fachserie 11, Reihe 4.1*.

428 Cf. OECD Stat, Graduates by field of education.

429 Cf. Zachmann (2004) in Ihsen et al. (2014).

430 Cf. Ihsen et al. (2014).

431 Cf. Ihsen et al. (2014).

432 Cf. GWK (2012).

433 Cf. GWK (2012).

434 Cf. GWK (2012).

435 Cf. http://www.dfg.de/foerderung/grundlagen_rahmenbedingungen/chancengleichheit/forschungsorientierte_standards/index.html (last accessed on 10 January 2014).

436 Cf. Dzwonnek (2013).
437 Cf. GWK (2013).
438 Cf. Kohaut and Möller (2012).
439 Cf. BMFSFJ (2013b).
440 Cf. Kohaut and Möller (2013).
441 The German Corporate Governance Code was adopted on 26 February 2002 by the Government Commission German Corporate Governance Code, which had been appointed by the Federal Minister for Justice in September 2001. The Code aims to present essential statutory regulations for the management and supervision of German listed companies in a transparent way.
442 Cf. http://www.corporate-governance-code.de/ger/kodex/index.html (last accessed on 10 January 2014).
443 Cf. Heidemann et al. (2013).
444 Cf. FIDAR (2013).
445 Cf. CDU, CSU and SPD (2013: 102). The coalition agreement states: "Non-executive boards of fully co-determined, listed business enterprises shall introduce a gender quota of at least 30 percent for new appointments from 2016. We will be developing statutory regulations which will provide that the respective chairs of the underrepresented sex shall remain vacant in the event that this quota is not achieved. As of 2015, listed or co-determined business enterprises shall be legally bound to define and publish binding targets for increasing the representation of women on non-executive boards, executive boards and in the top levels of management and to provide transparent reporting on the progress achieved. The first targets will have to be met within the 18th legislative period of the *Bundestag* and are not subject to subsequent downward adjustment."
446 It is not clearly stated whether the quota refers to the overall non-executive board or whether it only applies to newly appointed non-executive positions. To achieve an increase in the representation of women on non-executive boards, it will be essential to define ambitious goals and to establish clearly defined sanctions in the case of failure to achieve these goals.
447 Cf. Ahern and Dittmar (2012), as well as Nygaard (2011).
448 Cf. Matsa and Miller (2013).
449 Cf. http://www.europarl.europa.eu/news/en/news-room/content/20131118IPR25532/html/40-der-Sitze-in-Aufsichtsr%C3%A4ten-f%C3%BCr-Frauen (last accessed on 10 January 2014).
450 Cf. Kohaut and Möller (2013). Furthermore, the proportion of women in senior management roles should be considered according to the size of the establishment – also in the public sector. This would reveal that the representation of women significantly decreases as the size of the establishment increases. In public entities with 500 or more employees, the share of women in top management positions amounts to 20 percent, which is only slightly above that of the private sector (19 percent). Cf. Kohaut and Möller (2013).
451 Unless otherwise stated, this section is based on Solga and Pfahl (2009).
452 Cf. Smith et al. (2013).
453 At first glance, however, it is not clear whether a lack of options to combine family and working life does indeed have a negative effect on the success of female researchers. Surprisingly, a study on female researchers in German-speaking countries has shown that female researchers with children are more productive than female researchers without children. That said, the findings suggest that this is attributable to a selection process: only the most productive female researchers with children dare to pursue an academic career. Cf. Joecks et al. (2013).
454 Cf. Solga and Pfahl (2009).
455 Cf. Holst et al. (2012).
456 Cf. Bauernschuster and Schlotter (2013).
457 Cf. Herr and Wolfram (2009).
458 Cf. Blau and Kahn (2013). Whether the use of flexible working hours leads to positive or negative career consequences ultimately depends on individual motives and on the senior managers' perception of these motives. Cf. Leslie et al. (2012).

459 Cf. Ihsen et al. (2014).

460 In 2012, the average number of actual hours worked per week by female part-time employees in their main job amounted to 18.8 hours in Germany, 21 in Austria and 24.8 in Sweden. Cf. http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lfsa_ewhun2&lang=en (last accessed on 10 January 2014).

461 A number of companies, among them Ford and Fraport AG, are breaking new ground in this respect by providing job sharing models for executive staff. This will make it easier for employees to reconcile work and family life. Cf. http://www.erfolgsfaktor-familie.de/default.asp?id=514&pid=663 and http://www.erfolgsfaktor-familie.de/default.asp?-id=524&olfid=13 (last accessed on 10 January 2014). Furthermore, there are indications that gender-specific differences in salary are influenced by the structure and allocation of hours worked. According to these findings, individuals who work long hours are rewarded, while those with flexible working hours are disadvantaged. Cf. Goldin (2013).

462 Cf. Funken (2011), Peus and Welpe (2011).

463 Cf. Peus and Welpe (2011).

464 Cf. EFI (2013), Moss-Racusin et al. (2012).

465 Cf. Krause et al. (2013). There are no plans to turn this project into legislation; the Federal Anti-Discrimination Agency relies on voluntary commitment and aims to encourage companies to critically review their existing recruitment policy.

466 Cf. Niederle and Vesterlund (2007).

467 Cf. Leibbrandt and List (2012).

468 This section on Sweden is based on Ihsen et al. (2014).

469 Cf. Beaman et al. (2009).

470 Cf. http://www.nytimes.com/2013/09/08/education/harvard-case-study-gender-equity.html?pagewanted=all&_r=3& (last accessed on 10 January 2014).

471 Cf. Holzinger and Reidl (2012).

472 Cf. Swedish Discrimination Act.

473 Cf. EFI (2013).

474 Cf. EFI (2013).

475 Cf. EFI (2013).

476 Cf. EFI (2013).

477 Cf. Peus and Welpe (2011).

C 478 The systematic selection of international comparison countries is based, inter alia, on economy size and the national R&D intensity of the OECD and BRICS countries.

C 1 479 Baethge et al. (2014)

480 The ISCED classification of educational levels is the UNESCO standard to facilitate international comparisons of education systems across countries and is also used by the OECD. According to the ISCED classification, education can be divided into the following levels:

ISCED 0 Pre-primary education

– Nursery school;

ISCED 1 Primary education

– Primary school;

ISCED 2 Lower secondary education

– Hauptschule, Realschule, Gymnasium (grade 5 to grade 10);

ISCED 3 Upper secondary education

– Qualification to study at a university or university of applied sciences (Fachhochschulreife/Hochschulreife); without formal vocational qualification or completion of an apprenticeship.

– Qualification to practise an occupation, earned at a vocational school (Berufsfachschule or Kollegschule).

– Graduation from a one-year school in the healthcare sector;

ISCED 4 Post-secondary non-tertiary education
– Qualification to study at a university or university of applied sciences (Fachhochschulreife/Hochschulreife) plus completion of an apprenticeship.
– Fachhochschulreife/Hochschulreife plus qualification to practise an occupation, earned at a vocational school (Berufsfachschule or Kollegschule).
– Graduation from a one-year school in the healthcare sector;
ISCED 5B First stage of tertiary education B
– Master craftsman/tradesman or technician training (Meister/Techniker) or equivalent degree from an advanced trade and technical school (Fachschule).
– Graduation from a two-year or three-year school in the healthcare sector.
– Graduation from a specialised academy (Fachakademie) or a college of advanced vocational studies (Berufsakademie).
– Graduation from a public administration university of applied sciences (Verwaltungsfachhochschule).
– Graduation from a university of applied sciences of the former GDR (Fachschule);
ISCED 5A First stage of tertiary education A
– Degree from a university of applied sciences (Fachhochschule), including a degree from a school of engineering, a Bachelor's or Master's degree from a university of applied sciences, excluding final qualification earned at a public administration university of applied sciences.
– Degree from a tertiary education institution (Diplom certificate, university) and respective final examinations);
ISCED 6 Completion of doctoral degree
Cf. Müller (2009: 43), OECD (2011c: 31).

C 2 481 Cf. Schasse et al. (2014).

C 3 482 In this regard and in the following, cf. Rammer and Hünermund (2013).

483 Cf. in the following Rammer et al. (2013).

484 Cf. Blind (2002).

C 4 485 For a more detailed discussion on the grounds for and the effects of public R&D funding, cf. Chapter B 4 of the 2012 Report on the economic assessment of public R&D funding.

C 5 486 In this regard, cf. http://www.doingbusiness.org/about-us (last accessed on 10 January 2014), as well as Müller et al. (2013).

487 For a more detailed account, cf. http://www.doingbusiness.org/methodology/starting-a-business (last accessed on 10 January 2014). The values for the indicators for each individual country are calculated via a three-staged process (cf. in the following Müller et al 2013): as a first step, the World Bank's Doing Business team examines the applicable rules and regulations and develops a detailed list of all procedures officially required, as well as the time and cost to complete these procedures and the paid-in minimum capital requirements. As a second step, the list is submitted to experts in the respective countries who are asked to review the list for accuracy and make amendments if necessary. The experts in the countries usually comprise lawyers, tax advisors and government officials. As a third step, the World Bank team reviews the information provided by the experts and clarifies any discrepancies existing between the experts' data and the original research.

488 The standard business is defined as follows: (cf. in the following http://www.doingbusiness.org/methodology/starting-a-business, last accessed on 10 January 2014): (1) it is a limited liability company; (2) it operates in the economy's largest business city; (3) it is 100 percent domestically owned and has five owners, none of whom is a legal entity; (4) it has start-up capital of ten times income per capita, paid in cash; (5) it performs general industrial or commercial activities; (6) it leases the commercial plant or offices; (7) it does not qualify for investment incentives or any special benefits; (8) it has at least ten and up to 50 employees one month after the commencement of operations, all of them domestic nationals; (9) it has a turnover of at least 100 times income per capita; (10) it has a company deed of at least 10 pages.

489 Yet, country-specific data cannot be compared in full. (For a more detailed discussion cf. Müller et al 2014).

490 This official database draws on evaluations of the individual member countries' business registers. The values for Germany are provided by the Federal Statistical Office's business statistics, which are derived from the German business register. Cf. in more detail Müller et al. (2013).

491 The Mannheim Enterprise Panel (MUP) is a ZEW panel data set of businesses located in Germany. It is maintained in cooperation with Creditreform, the largest credit information bureau in Germany. The term enterprise, as employed by the MUP, refers to economically active enterprises only, while the term start-up refers to original newly formed companies only. This is the case provided that economic activities are taken up that have not been previously carried out, and provided the activities are the main source of income of at least one person. The closure of a company occurs when a company is not economically active anymore and ceases to offer products on the market.

492 The MUP provides a fairly narrow definition of economically active enterprises, market entries and market exits. As a result, minor economic activities may not be covered by the MUP.

C 6 493 Cf. Neuhäusler et al. (2014:15).

C 8 494 The whole section of C 8 is based on Schiersch and Gehrke (2014).

D 495 The following explanations are based on Gehrke et al. (2013) as well as further methodological information provided by Dr. Gehrke.

496 Only mechanical engineering is close to this threshold, i.e. this industry has the lowest R&D intensity of all research-intensive industries. All other research-intensive industries are well above average.

497 In the early 1990s, R&D intensity in the chemical industry amounted to approx. 3.5 percent on an OECD average. This value had dropped to 2.5 percent by 2003. Cf. Rahmer et al. (2005).

498 The gap between high-value technology and cutting-edge technology is confirmed by German R&D statistics that allow for an in-depth analysis at the three and four-digit industry level.

499 To account for borderline cases, additional information from the Mannheim Innovation Panel, the cost structure survey, the workforce statistics and the patent statistics are also considered.

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