REPORT ON RESEARCH,
INNOVATION AND TECHNOLOGICAL
PERFORMANCE IN GERMANY

COMMISSION OF EXPERTS
FOR RESEARCH
AND INNOVATION

EFI

REPORT

2020 2021 2022

2023 2024 2025

2026 2027 2028

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REPORT 2020

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The Commission of Experts wishes to emphasize 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 Commission of Experts' coordination office and the staff of the Commission Members.

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Foreword

The past year was one of comprehensive personnel changes for the Commission of Experts. As a result of the retirement of several Commission Members in line with the rotation system, the current annual report was prepared by a largely new Commission of Experts and a new Chairperson. The content of the reports remains bound to the remit formulated by the Federal Government in its decision to set it up: the Commission of Experts analyses the structures, trends, performance and prospects of the German research and innovation system in the context of an international comparison, and drafts recommendations for action for its further development. Furthermore, it addresses a broad spectrum of different issues in research and innovation policy. This spectrum ranges from basic research, new technological developments and the transfer of knowledge and technology to entrepreneurial research and development activities, innovative start-ups, education and training, and aspects of governance.

Against the background of current global developments, the Commission of Experts will devote more attention in its future reports to the analysis of transformative changes – e.g. digitalization or the Energy Transition – which are based on fundamental technological innovations and linked to major societal challenges such as climate change.

In addition to technological and economic aspects, the Commission of Experts would like to increasingly focus on the ecological and social dimensions of these developments. In doing so, it considers on the one hand related new challenges for the research and innovation system, and, on the other hand, the emerging opportunities for solving urgent societal problems.

Innovation is not an end in itself. It aims to strengthen the prosperity and cohesion of society in line with environmental sustainability. In this context, Germany‘s research and innovation system must be continuously enhanced to create suitable legal, institutional and infrastructural framework conditions for economically profitable, socially acceptable and ecologically sustainable technological and social innovations.

A continuous further development of the research and innovation system in this sense requires policy-makers, businesses and society to look ahead and show a high degree of agility, responsiveness – and also a willingness to take risks. The tasks are manifold. In the coming years, far-reaching adjustments will have to be made in Germany‘s core industries to maintain their high international competitiveness. Moreover, existing sustainability targets can only be reached if there is a shift away from hitherto dominating technologies and behaviour and if the societal consequences are socially cushioned.

Yet the changes entail not only risks, but also great opportunities. Fundamental innovations and their follow-on innovations can provide fresh impetus for developing productivity across the board. This opens up an opportunity for Germany to re-accelerate its recently decelerating productivity growth and to reverse the declining trends in innovator and start-up rates.

The Commission of Experts will continue to provide forward-looking analytical support for these developments in the future and formulate proposals for actively shaping upcoming change processes. With empirically founded information, it would like to contribute to Germany‘s ability to successfully meet current and future challenges and take advantage on a broad basis of the opportunities that arise.

The Commission of Experts has selected the following topics for the five chapters of its current Annual Report:

In chapter A 1, the Commission of Experts acknowledges measures taken by the Federal Government last year to implement the High-Tech Strategy 2025. Two new instruments of research and innovation policy have been created with the introduction of tax incentives for research and the establishment of the Federal Agency for Disruptive Innovation. Implementation of the Artificial Intelligence Strategy has begun and should be pursued vigorously.

In 2019, the Federal Government and the Länder reached important agreements in the field of science policy, and these are discussed in chapter A 2. The Commission of Experts supports the increased importance being assigned to the transfer of knowledge and technology in the fourth Pact for Research and Innovation. It welcomes the fact that the ‚Contract on the Future Strengthening of Studying and Teaching‘ was concluded for an unlimited period. However, the Commission of Experts warns against allowing the number of permanent non-professorial academic employment relationships to grow disproportionately when implementing the Contract on the Future.

To mark the 30th anniversary of German reunification, in chapter B 1 the Commission of Experts examines the innovation activities of companies in east and west Germany, taking structural differences into account. The result is that the innovation activities of east German companies have converged with that of west German companies. However, they are still behind when it comes to launching innovation activities or introducing innovations to the market. The Commission of Experts recommends that companies not engaging in research and development should be more closely integrated into research and innovation funding and supported in bringing innovations to market.

In chapter B 2, the Commission of Experts analyses the relationship between cyber-security and innovation. This reveals that cyber threats have a negative impact on corporate innovation activities. Furthermore, cybersecurity is itself the subject of innovation activities. Measured in terms of the number of patent applications, Germany is a long way behind the USA, China and Japan. In particular, the Federal Government should promote the teaching of cybersecurity skills, secure digital infrastructures, promote R&I activities in cybersecurity, and support small and medium-sized enterprises in implementing cybersecurity measures.

In chapter B 3, the Commission of Experts examines the exchange of knowledge and technology between Germany and China. There is concern in Germany that knowledge and technology exchange with China will lead to a one-sided outflow of know-how and thus weaken Germany‘s scientific and economic performance. In order to prevent this happening, the Federal Government should work to achieve a level playing field in direct investment, examine takeovers in the field of sensitive technologies more carefully, and improve overall knowledge about China in Germany.

Berlin, 19 February 2020

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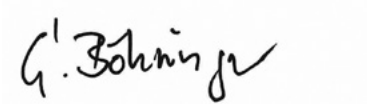

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EXECUTIVE SUMMARY

Executive summary

A Current developments and challenges

A 1 Implementation of the High-Tech Strategy 2025

Germany's R&D intensity rose to 3.13 percent in 2018. This is an important step towards reaching the target of spending 3.5 percent of GDP on R&D by 2025.

The entry into force of the Law on Tax Incentives for R&D (Forschungszulagengesetz) means that the instrument of tax incentives for R&D activities is at last also available in Germany. The planned evaluation will have to show whether the design of the instrument can have the desired incentive effect.

The newly founded SprinD GmbH aims to promote radical innovations. The Commission of Experts strongly believes that management should be given the highest degree of independence from political control in this context.

The Commission of Experts calls on the Federal Government to back up the measures listed in the Blockchain Strategy with milestones and to document the achievement of the milestones transparently.

In the opinion of the Commission of Experts, the effects intended with the planned GAIA-X data infrastructure can only be achieved if GAIA-X is implemented quickly, has a critical minimum capacity and guarantees a high degree of user-friendliness.

A 2 Science policy

The fourth Pact for Research and Innovation (PFI IV) gives non-university science organizations a high level of planning security. The Commission of Experts supports the increased importance being assigned to the transfer of knowledge and technology in the PFI IV research-policy objectives.

The Commission welcomes the fact that the Federal Government is participating permanently in the financing of teaching under the “Contract for the Future Strengthening of Higher Education and Teaching”. It also regards the introduction of a quality-oriented system for the allocation of funds as a positive development.

However, the Commission sees problems in the focus on expanding permanent employment relationships for staff involved in studying and teaching. It is concerned that this will result in a disproportionate increase in the number of permanent non-professorial academic staff.

A legally dependent organizational unit is being set up to implement the objectives set out in the administrative agreement on 'Innovation in Higher Education Teaching'. The Commission of Experts criticizes the fact that this new organizational unit was not initially set up for a limited period of time and that it is relatively open to influence from political representatives.

The Commission of Experts again calls for an increase in the DFG's programme allowance, since it will otherwise not fully cover overhead costs in most cases.

B Core topics 2020

B 1 East Germany as a location for innovation – 30 years after reunification

Even 30 years after reunification, there are still major structural differences between east and west Germany which impact inter alia on corporate innovation activities. A comparison of structurally similar companies shows that the level of innovation activity in east German companies has converged with that of west German companies in recent years. However, there is still a need for east German companies to catch up when it comes to launching innovation activities and introducing innovations to the market.

East German companies cooperate more on their innovation projects than west German companies, whereby their cooperation activities are more frequently regionally oriented.

– One important task of the Federal Government's R&I policy is to strengthen Germany's position in global competition. The Commission of Experts therefore believes that R&I policy should continue to focus on promoting excellent innovation projects, which exist in both east and west Germany.

– The Commission of Experts welcomes the fact that the Federal Government will refrain from providing special R&I support for east German companies after the expiry of Solidarity Pact II. In its view, it makes sense to support R&I in structurally weak regions chosen on the basis of regional characteristics and not according to the borders between Länder. Such funding, too, should target projects chosen according to excellence criteria.

– Furthermore, the Commission of Experts advocates an innovation-oriented structural policy. This promotes the potential of structurally weak regions, for example through infrastructure measures, and in this way aims to increase their overall willingness and ability to innovate.

– In order to motivate more companies in structurally weak regions to engage in innovation activities, companies without R&D should be integrated more closely into R&I funding. In other words, non-technical and social innovations should also be given more support.

– The Commission of Experts recommends that in future R&I policy should be more oriented towards giving companies in structurally weak regions support in launching new products and services onto the market, thus increasing the innovator rate.

– The Commission of Experts attaches importance to regional networking among innovation actors. However, it suggests placing greater emphasis on supra-regional and international forms of cooperation and networking in R&I funding.

B 2 Cybersecurity

Ongoing digitalization and digital networking make companies more vulnerable to cyberattacks. Many companies are therefore very aware of the need to protect their information technology. Existing cyber threats have a negative impact on corporate innovation activities – e. g. creating a disincentive to plan new innovation projects or launch planned projects.

Cybersecurity itself is also the subject of innovation activities. Measured in terms of cybersecurity patents, Germany is a long way behind the USA, China and Japan.

The Commission of Experts recommends that the Federal Government should take the following measures:

– Teaching cybersecurity skills in vocational education and training as well as in higher education should be further promoted to meet the growing demand for cybersecurity experts. Such moves should cover not only technical aspects, but also deal with legal and ethical issues.

– The approval of digital infrastructure components should be based on criteria that apply throughout the European single market. These criteria should take into account technical and non-technical aspects and apply equally to EU and non-EU suppliers. Corresponding initiatives by the European Commission, e. g. on the roll-out of 5G networks, should be supported.

– The Cyber Agency should begin operations quickly and practise demand-driven procurement to promote innovative projects that help protect Germany's technological sovereignty in cybersecurity. It is important here to constantly and openly follow new technological developments to be able to react flexibly to changing needs. An evaluation of the Cyber Agency should examine what stimuli it generates for R&I activities in cybersecurity.

– It is particularly important to provide easily accessible information and advisory services for SMEs. The effectiveness of existing programmes to promote cybersecurity in SMEs should be evaluated and adapted to the constantly changing threat situation.

– In order to improve the information available on the quality of cybersecurity products and services, initiatives should be supported which are aimed at developing minimum standards and certification systems, particularly at the European level.

– It needs to be established whether the existing reporting obligations need to be extended in order to improve the information available on cyber risks and to deal more effectively with cyber threats.

B 3 Exchange of knowledge and technology between Germany and China

There is concern in Germany that the exchange of knowledge and technology with China will lead to a one-sided outflow of know-how and weaken Germany's scientific and economic performance. The available empirical evidence does not support the hypothesis that Chinese direct investment in Germany has led to a weakening of the economic performance by the affected companies. Nonetheless, corporate investments and takeovers by Chinese investors in principle involve the risk of political and strategic influence being exerted.

- The Federal Government should push strongly for a level playing field in direct investment for German and Chinese companies.

- The Commission of Experts supports the BMWi's plans to examine corporate takeovers by foreign investors more thoroughly in the field of sensitive technologies. The areas of technology to be included should be announced first. In addition, clear and transparent auditing criteria need to be developed.

- In China, science is subject to direct government influence. In order to ensure that scientific cooperation with China benefits both sides, it is necessary to appropriately inform and sensitize the German actors involved.

- A central competence centre should be set up to advise German scientists and provide expertise on legal issues relevant to cooperation and research. The competence centre should furthermore systematically collect and evaluate information on experience and problems with German-Chinese cooperation and process it for research and administrative staff at research institutions.

- Research and teaching that contribute to the understanding of current political, societal and economic developments in China should be strengthened. In this context, attention should be paid on teaching good Chinese language skills.

- There should be an intensive and continuous exchange on the framework conditions and prospects of scientific cooperation between Germany and China, this should be coordinated with the European partners. The Commission of Experts recommends that suitable formats for further cooperation should be created soon following the expiry of the BMBF's China strategy and the termination of the Sino-German Innovation Platform.

CURRENT DEVELOPMENTS AND CHALLENGES

A 1 Implementation of the High-Tech Strategy 2025

In 2018, expenditure on research and development (R&D) accounted for 3.13 percent of gross domestic product (GDP),[1] i.e. Germany's R&D intensity rose again. That is an important step towards reaching the target formulated in the High-Tech Strategy 2025 (Hightech-Strategie 2025, HTS 2025) of spending 3.5 percent of GDP on R&D by 2025.[2]

In 2019, the introduction of tax incentives for R&D, signalled in the HTS 2025, and the establishment of the Federal Agency for Disruptive Innovation, created two new instruments of R&I policy. In the same year, the Federal Government set up the Next Generation Cluster Initiative (Zukunftscluster-Initiative), thus launching a new, major cluster programme after the Leading-Edge Cluster Competition had expired. In its newly adopted Blockchain Strategy, the Federal Government identifies measures designed to help tap the potential of blockchain technology; and in its ‚Interim Report: AI Strategy, One Year On' (Zwischenbericht ein Jahr KI-Strategie), it presents its activities in the field of artificial intelligence (AI). The pricing of carbon dioxide (CO_2), as envisaged in the Climate Protection Programme 2030, aims to also provide incentives for climate-friendly innovation.

Introduction of R&D funding through tax incentives

The Law on Tax Incentives for R&D (Forschungszulagengesetz) was passed by the Bundestag and Bundesrat in 2019 and came into force at the beginning of 2020.[3] Hence, the instrument of offering tax incentives for R&D is now also available in Germany, as had long been called for by the Commission of Experts.[4]

Companies that conduct their own R&D and companies that award R&D contracts to third parties are eligible for tax-based R&D funding.[5] The Commission of Experts welcomes the fact that R&D contracts are attributed to the companies that award the contracts. On the one hand, this is particularly important for SMEs that have little in the way of in-house R&D resources. On the other hand, the transfer of knowledge and technology from science to business is further boosted when R&D contracts are awarded to tertiary education institutions and non-university research institutions.

In cases where a company conducts its own R&D projects, the eligible costs result from the costs of the R&D personnel employed.[6] In cases where R&D contracts are awarded, the pro-rata contract value is recognized.[7] The basis of assessment corresponds to the eligible expenses of the respective financial year up to a maximum of €2 million.[8] The tax-based R&D funding amounts to 25 percent of this assessment basis, i.e. up to a maximum of €500,000 per financial year. Consequently, companies whose eligible expenses are below €2 million benefit more from the research subsidy relatively than companies whose eligible expenses exceed this threshold. The planned evaluation of the research subsidy will have to show whether its design can develop the desired incentive effect.

The tax-based R&D funding can be claimed after the end of the financial year in which the eligible expenditure was incurred. It is credited against income or corporation tax[9] in such a way that the research subsidy for a given year can be credited against the next income or corporation tax – irrespective of the assessment period. The Commission of Experts' assessment of this is positive. For start-ups and SMEs in particular, the sooner tax-based R&D funding has an impact on liquidity, the greater the incentive effect.

Furthermore, for start-ups it is important that they also benefit from tax-based R&D funding if their tax debt is low or non-existent. If the tax-based R&D funding to be credited exceeds the assessed income or corporation tax, it is paid out.

Federal Agency for Disruptive Innovation founded

In its 2018 annual report, the Commission of Experts advocated the establishment of a Federal Agency for Disruptive Innovation.[10] The Federal Government announced in the HTS 2025 that it would set up an agency of this kind.[11] A corresponding key issues paper was already adopted by the cabinet in August 2018.[12]

In the summer of 2019, the founding director of the Federal Agency for Disruptive Innovation was named, and Leipzig was selected as the agency's location. The establishment of the Federal Agency for Disruptive Innovation (SprinD GmbH) then followed in autumn 2019.[13] Policy-makers have an opportunity to influence the entrepreneurial decisions of SprinD GmbH via the shareholders' meeting and the supervisory board. In this context, the political representatives are called upon to strike an appropriate balance between the responsible use of taxpayers' money and entrepreneurial risk. The Commission of Experts strongly believes that the management should be given a maximum degree of independence from political control and departmental thinking and, above all, should itself determine the thematic focus of SprinD GmbH.

Next Generation Cluster Initiative launched

In summer 2019, the Federal Ministry for Education and Research (Bundesministerium für Bildung und Forschung, BMBF) launched the Next Generation Cluster Initiative to promote the development of regional clusters in innovative fields with high growth potential.[14] The aim is to take certain state-of-the-art technologies, scientific methods and instruments from research into application as quickly as possible.[15] The initiative is designed as a multi-stage, competitive procedure and makes provision for several rounds of competition. In what is known as the conception phase, the innovation networks are each funded with up to €250,000. The innovation networks selected for the implementation phase can be funded with up to five million euros per year respectively for up to nine years. Although the funding policy does not exclude any topics or fields of application, it does specify fields of action that are regarded as priorities.[16] The Commission of Experts supports the initiative's general objective, but criticizes the fact that the funding guideline was not formulated in a way that is completely open to all topics and technologies.

Federal Government's Blockchain Strategy adopted

In September 2019, the Federal Cabinet adopted the Federal Government's Blockchain Strategy (Blockchain-Strategie der Bundesregierung).[17] The aim is to use the opportunities offered by blockchain technologies and to mobilize their potential for digital transformation.[18] The Federal Government drew up its Blockchain Strategy on the basis of a consultation process and plans to continue the dialogue with the private business sector, civil society and experts.[19] The Commission of Experts welcomes the fact that the Federal Government is systematically seeking the expertise of the stakeholders in its Blockchain Strategy in order to identify the kind of framework conditions that can hinder the development and scaling of blockchain applications.

In its Blockchain Strategy, the Federal Government formulates five fields of action,[20] allocates measures to them, and designates responsibilities. The Commission of Experts calls on the Federal Government to back up the measures listed with milestones and transparently document the achievement of the milestones.

Implementation of the AI Strategy has begun

The Federal Government's AI Strategy (Strategie Künstliche Intelligenz der Bundesregierung) was adopted by the Federal Cabinet in November 2018.[21] In November 2019, the Federal Government published the ‚Interim Report: AI Strategy, One Year On', listing measures that are being implemented or planned.[22] The key measures of the AI strategy include the further development of the German Competence Centres for AI (Kompetenzzentren für KI-Forschung), the creation of 100 new professorships, the development of a data infrastructure, and support for the transfer of knowledge and technology.

In addition to the German Research Centre for Artificial Intelligence (Deutsches Forschungszentrum für Künstliche Intelligenz, DFKI), the BMBF is currently funding five other German Competence Centres for AI.[23] In its AI Strategy, the Federal Government has announced its intention to further develop the existing German Competence Centres for AI on a supraregional basis and expand them into a national network.[24] Funding for the existing centres is to be doubled by the year 2022.[25] In the long term, the Federal Government plans to stabilize the funding

of the centres together with the Länder in which they are located.[26] With regard to the performance and international visibility of Germany's AI locations, the Commission of Experts welcomes the fact that the Federal Government's focus is on strengthening and internationally networking existing centres and not on setting up new ones.

In line with its AI Strategy, the Federal Government aims to ensure that AI has a broad and stable base at tertiary education institutions by creating at least 100 additional professorships.[27] In order to attract leading scientists and scholars from abroad, thirty Alexander von Humboldt Professorships in the AI field have been advertised.[28] In addition, the establishment of new AI professorships is to be promoted by expanding the German Competence Centres for AI.[29] Furthermore, the Federal Government intends to ensure scientific expertise in the AI field by strengthening the promotion of young researchers.[30] The Commission of Experts expressly supports this project.

Together with partners from the business and science communities, the Federal Government intends to create a networked and open data infrastructure with its GAIA-X project presented in October 2019.[31] It aims to make available data and services for AI applications while guaranteeing digital sovereignty.[32] The Commission of Experts supports the project's objectives, since improved data availability for German and European actors will create new innovation potential in the AI field. However, the Commission of Experts also points out that the effects intended can only be achieved if GAIA-X is implemented quickly, has a critical minimum capacity and guarantees a high degree of user-friendliness.[33]

In 2019, the Federal Government conducted an innovation competition called ‚Artificial Intelligence as a Driver for Economically Relevant Ecosystems' and launched a pilot innovation competition entitled ‚Energy-efficient AI System'.[34] Alongside these two application-related innovation competitions, the Federal Government is implementing further measures to promote the transfer of knowledge and technology in the AI sector. These include the use of so-called AI trainers and the development of the AI Map (KI-Landkarte).[35] The Commission of Experts calls on the Federal Government to further promote the transfer of knowledge and technology in the AI field.

Climate Package under way

In its 2019 Report, the Commission of Experts pointed out that innovative technologies and business models can make a decisive contribution to the Energy Transition. Many technologies considered important by experts have already reached market maturity. However, their diffusion is inhibited by the fact that negative external effects of CO_2 emissions are not being internalized.[36] The Fuel Emissions Trading Act was adopted as part of the implementation of the Climate Protection Programme 2030 presented by the Federal Government in October 2019 – also known as the Climate Package. It provides for the introduction of tradeable emission allowances for the heating and transport sectors in 2021.[37] In the years 2021 to 2025, the allowances will be sold at a fixed price, from 2026 onwards by auction. In this context, pricing will take place within a fixed price corridor in 2026. The Fuel Emissions Trading Act provides for a gradual increase in the fixed price for emission allowances from €10 to €35 per allowance in the years 2021 to 2025, and for a price corridor between €35 and €60 per emission allowance in 2026.[38] In addition to adjustments to tax law, the compromise reached by the Mediation Committee of the Bundestag and Bundesrat on the tax measures in the Climate Protection Programme 2030 includes a redefinition of the prices for emission allowances.[39] Accordingly, the emission price is to gradually rise from €25 to €55 per emission allowance in the period from 2021 to 2025 and will be between €55 and €65 in 2026. In the opinion of the Commission of Experts, the CO_2 prices currently provided for in the Fuel Emissions Trading Act are not high enough to sustainably promote the use of climate-friendly technologies and business models. It believes that the emission prices proposed by the Mediation Committee are more likely to have the desired effect.

In order to ensure social acceptance of CO_2 pricing, the Commission of Experts advocates mitigating disproportionate energy-cost burdens for low-income households by making a flat-rate reimbursement.[40] However, compensating measures should not impair the effectiveness of CO_2 pricing. The Commission of Experts therefore considers it counter-productive to increase the commuter allowance and grant a mobility premium for the period 2021 to 2026 as provided for in the ‚Act for the Implementation of the Climate Protection Programme 2030 in Tax Law'.[41]

Science policy A 2

The agreements between the Federal Government and the Länder on the third Pact for Research and Innovation (Pakt für Forschung und Innovation, PFI III), the Higher Education Pact 2020 (Hochschulpakt 2020) and the Programme to Improve Study Conditions and the Quality of Teaching and Mentoring (Quality Pact for Teaching, Qualitätspakt Lehre) will all expire at the end of this year. In June 2019, the heads of the Federal and Länder Governments adopted corresponding follow-up agreements – the fourth Pact for Research and Innovation (PFI IV), the ‚Contract for the Future Strengthening of Higher Education and Teaching' (Zukunftsvertrag Studium und Lehre stärken) and the agreement on ‚Innovation in Higher Education Teaching' (Innovation in der Hochschullehre).

Planning security for non-university science organizations

For the period 2021 to 2030, the PFI IV provides for an annual increase of three percent in Federal and Länder funding for non-university science organizations.[42] At ten years, the PFI IV's term is significantly longer than the previous five-year pacts for research and innovation. This gives the science organizations a great deal of planning security.

The PFI IV formulates five research-policy objectives to be pursued by the science organizations. The objectives are entitled ‚Promoting dynamic development', ‚Strengthening the transfer process in business and society', ‚Consolidating networking', ‚Attracting and retaining the best talents' and ‚Strengthening research infrastructures'. They are closely linked to the objectives of the PFI III,[43] but also include changes in emphasis. The Commission of Experts supports the increased importance being assigned to the transfer of knowledge and technology. For example, the PFI IV has incorporated an agreement according to which science organizations should develop new instruments of knowledge and technology transfer and use internal incentive instruments to acknowledge and promote successful transfers. In addition, the Commission of Experts supports the objective stated in the PFI IV of strategically orienting the transfer of knowledge and technology also towards SMEs.

The science organizations commit themselves respectively in target agreements to implementing the research-policy objectives by taking measures of their own. The current target agreements relate to the first five years of the PFI IV. They are to be renegotiated in 2025 for the second five years. The Commission of Experts expects suitable indicators to be developed so that the Joint Science Conference (GWK) can make a well-founded assessment of the results achieved up to that point. International benchmarks can also contribute to this, as mentioned in the PFI IV. The target agreements should then be updated on this basis.

Federal Government permanently involved in the financing of higher education teaching

The ‚Contract for the Future Strengthening of Higher Education and Teaching' aims to achieve a high quality of study and teaching throughout Germany, good study conditions across the entire German higher education landscape, and to ensure that available study capacity remains in line with demand.[44] It was concluded for an unlimited period of time on the basis of Article 91b (1) of the Basic Law for the Federal Republic of Germany. The Federal Government is providing €1.88 billion per year for the implementation of the Contract for the Future between 2021 and 2023. As from 2024, it will increase its budget to €2.05 billion per year. The Commission of Experts welcomes the fact that the Federal Government is now permanently involved in the financing of teaching.[45]

The Länder undertake to provide additional funds matching the federal funding received each year. They must report the provision and use of federal funds and their additional own funds every year in a standardized form. If a state fails to meet its funding commitments under the Contract for the Future, its entitlement to federal funding is reduced accordingly. The Commission of Experts regards it as appropriate to include this sanction mechanism in the Contract for the Future.

The percentage increase in funds in the Contract for the Future initially matches that of the PFI IV. If, on the basis of the Higher Education Pact funds for 2020,[46] the funds were increased by 3 percent each year, the tertiary education institutions would not be in a better position in the period 2021 to 2027 than they are now with the funds agreed for the Contract for the Future. In 2027, the Federal and Länder governments will discuss and decide on any needs for financial adjustment.

While the main aim of the Higher Education Pact is to expand the capacity available for additional first-year students,[47] the Contract for the Future focuses primarily on improving the quality of teaching in higher education. Within the framework of the Higher Education Pact, the Federal Government allocates funds to the Länder on the basis of the number of first-year students. The allocation of funds under the Contract for the Future additionally takes into account the number of students within the standard period of study plus two semesters, as well as the number of graduates. The Commission of Experts supports this first step towards a quality-oriented allocation of funds.[48]

All Länder are obliged to draw up seven-year written commitments containing statements on objectives, priorities and measures for implementing the Contract for the Future. Declarations on the expansion of permanent employment relationships for full-time academic and artistic staff involved in study and teaching are an obligatory component of this. The Commission of Experts is concerned that this will result in a disproportionate increase in the number of permanent non-professorial academic staff. It is of the opinion that employment relationships in the field of non-professorial academic staff should generally be linked to qualification targets. By limiting the duration of the corresponding employment relationships, the respective following graduate cohorts also have an opportunity to qualify.[49]

The Commission of Experts welcomes the fact that the Contract for the Future provides for a regular review by the German Council of Science and Humanities (Wissenschaftsrat), the results of which must be taken into account in discussions between the Federal Government and the Länder on the need for adjustments in content and funding.

Separate organization for Innovation in Higher Education Teaching is in the pipeline

The administrative agreement on ‚Innovation in Higher Education Teaching' aims to support tertiary education institutions in the quality-oriented further development of study and teaching.[50] Incentives are to be created for tertiary teachers and managements of tertiary education institutions to continue working towards improvements in the quality of study and teaching. The Commission of Experts supports this aim and advocates using tertiary institutions' experience and ideas from the Quality Pact for Teaching in its implementation.

Like the Contract for the Future, the administrative agreement on ‚Innovation in Higher Education Teaching' was also concluded for an indefinite period of time on the basis of Article 91b (1) of the Basic Law. In order to implement the objectives set out in the administrative agreement, the Federal Government and the Länder will finance a legally dependent organizational unit. In December 2019, Toepfer Stiftung gGmbH was selected as the supporting organization following an expression-of-interest procedure.[51] The tasks of the organizational unit include project funding, the promotion of exchange and networking, and the promotion of knowledge transfer. A committee involving the Federal Government and the Länder will take all the essential decisions relating to the organizational unit. The project-selection committees will also include representatives of the Federal and Länder Governments. The Commission of Experts criticizes the fact that the new organizational unit was not initially set up for a limited period of time and that it is relatively open to influence from political representatives.

Programme allowance remains unchanged at a low level

The German Science Foundation (Deutsche Forschungsgemeinschaft, DFG) programme allowance, the second pillar of the Higher Education Pact, serves to cover the indirect project costs associated with DFG funding.[52] After the expiry of the Higher Education Pact 2020, the DFG programme allowance will be granted on the basis of the ‚Implementation Agreement on the GWK Agreement on Joint Funding by the German Research Foundation' (AV-DFG).[53] It will remain unchanged at 22 percent until 2025. As from 2026, the Federal and Länder Governments will enter into negotiations on the level of the percentage. The Commission of Experts again calls for an increase in the DFG's programme allowance,[54] since in most cases it will otherwise not fully cover overhead costs.[55]

CORE TOPICS 2020

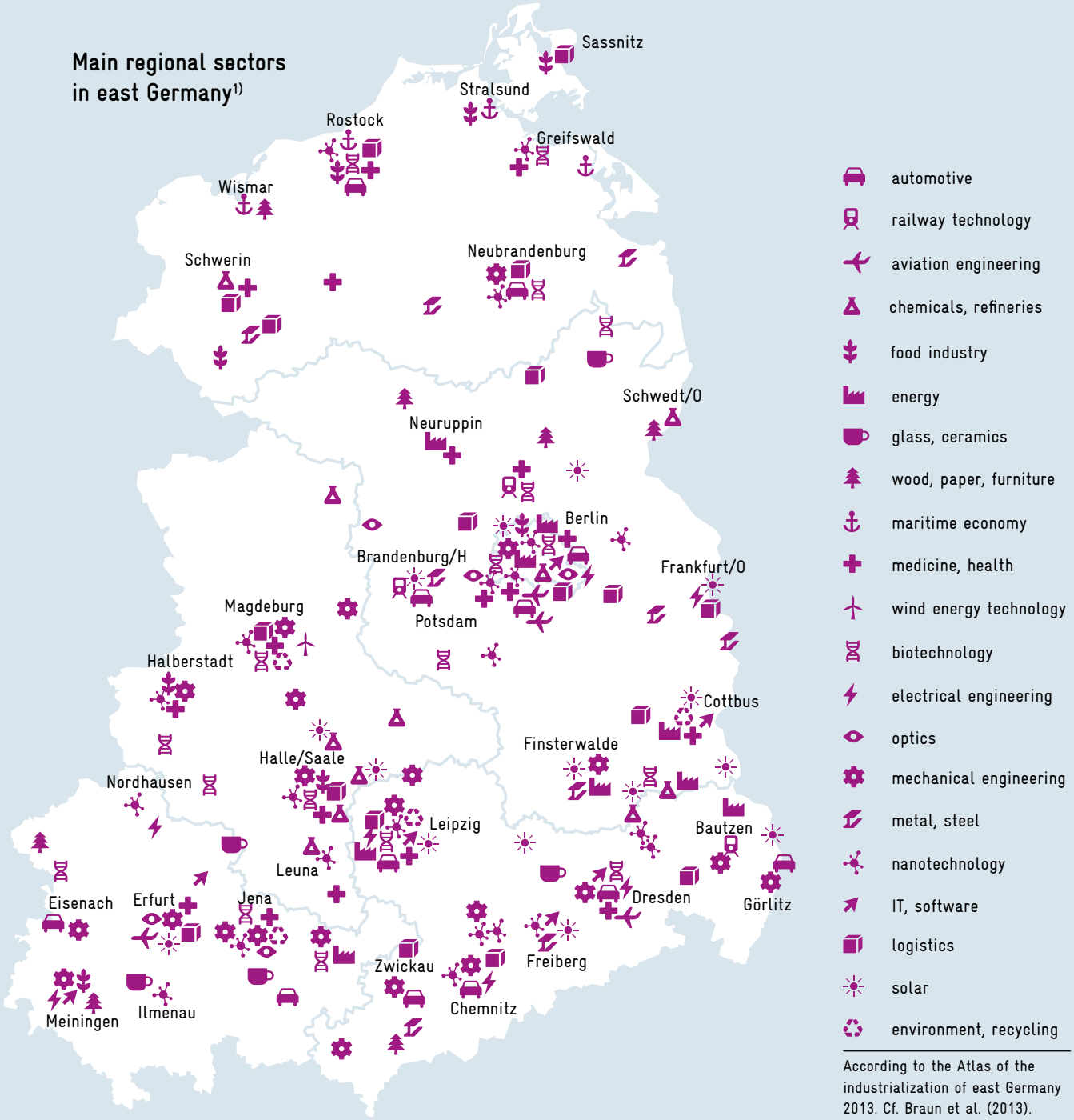
B

B 1 East Germany as a location for innovation – 30 years after reunification

Download data

There are still major structural differences between east and west Germany which impact inter alia on corporate innovation activities. A comparison of structurally similar companies shows that the level of innovation activity in east German companies has converged with that of west German companies in recent years.

Main regional sectors in east Germany[1)]



According to the Atlas of the industrialization of east Germany 2013. Cf. Braun et al. (2013).

Comparison of east and west German companies with similar structures[2)]

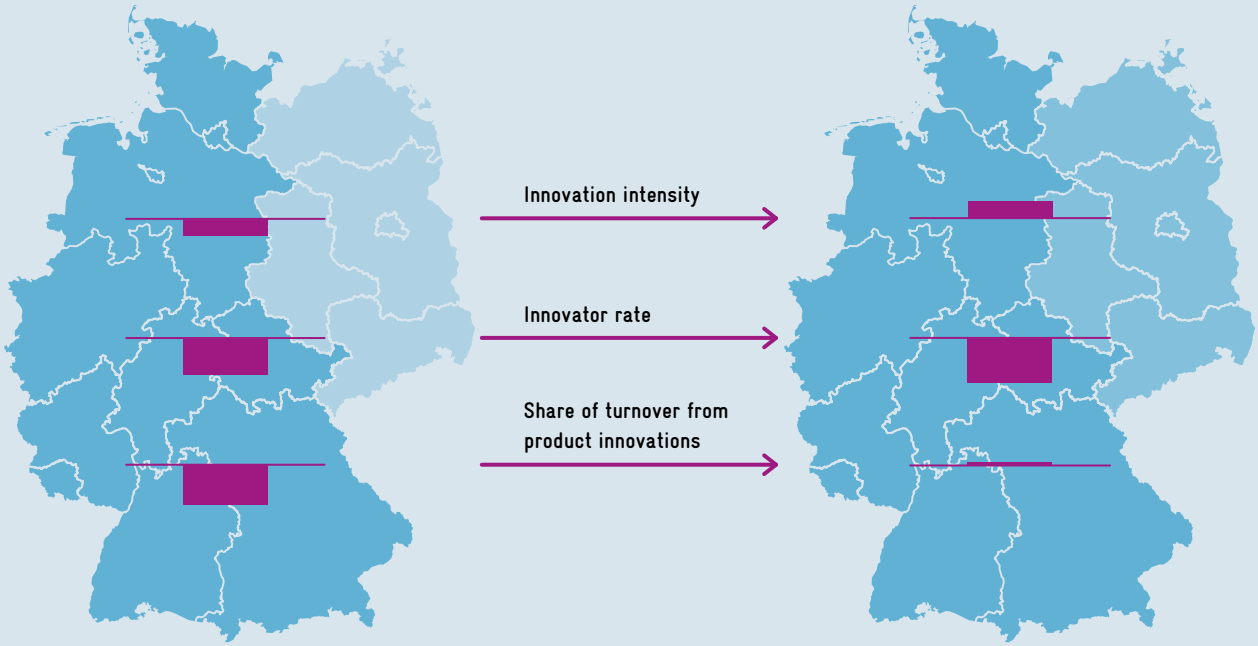
A 'matching' approach is used to identify those differences in innovation activities between east and west German companies that are not attributable to regional differences in the observable structural features. For this purpose, observable structural features such as the companies' size, sector and age are taken into account, i.e. only companies in east and west with similar observable structural features are compared.

Non-structurally adjusted deviation

Deviation of companies in east Germany compared to companies in west Germany

Structurally adjusted deviation

Deviation of companies in east Germany compared to companies in west Germany



Legend

While figures that have not been structurally adjusted show that the share of turnover from product innovations is currently lower in east German companies than in west German companies, structurally adjusted figures show hardly any differences between east and west German companies in this field.

See chapter D 7 for a list of sources of infocharts.

B 1 East Germany as a location for innovation – 30 years after reunification

This chapter reflects on the 30th anniversary of German reunification by highlighting east Germany's current innovation performance and its development in this field in recent years – especially in comparison to west Germany. Innovation is regarded as an important driver of overall economic productivity and thus of the development of income and welfare in an economy.[56] Studies show that east Germany has been able to considerably close the productivity gap between east and west Germany since reunification:[57] in 1991, productivity in east Germany was around 45 percent of the west German level; by 2018 it had reached about 83 percent.[58] After a considerable narrowing of the gap in the first years after reunification, however, the adjustment has slowed down markedly.[59] This is attributed primarily to structural differences between the east German and west German economies.[60]

East Germany differs structurally from west Germany primarily in the following aspects: the widespread lack of corporate headquarters of large multinational corporate groups; a comparatively high share of young small and medium-sized enterprises (SMEs) engaged in all economic activities; a disproportionate fraction of non-research-intensive industry; and a relatively high share of non-knowledge-intensive corporate services. At the same time, however, the east German economy is also characterized by a disproportionately high share of cutting-edge technology sectors,[61] including, for example, aerospace and pharmaceuticals.[62] In addition, there are more regions that are structurally weak in east Germany, where location conditions for innovation activities are comparatively unfavourable, inter alia in terms of the technical and knowledge infrastructure (e.g. broadband, transport, linkages to scientific institutions).[63]

This chapter examines the innovation activity of companies in east and west Germany, taking structural differences into account. In addition, the development of patent applications and start-ups, the cooperation activities of innovation-active companies, and the promotion of research and innovation (R&I) in east Germany are examined.

Development of innovation activity among east German companies

Based on data from the Stifterverband and a study conducted for the Commission of Experts by the Leibniz Centre for European Economic Research (ZEW – Leibniz-Zentrum für Europäische Wirtschaftsforschung), this section compares the development of innovation activity by companies in east Germany over the last 20 years (in most cases from 1997 to 2017) with that of west German companies. In this analysis, east Germany includes all the new Länder (i.e. the former German Democratic Republic) plus Berlin; Berlin plays a special role within east Germany. West Germany includes the old federal states excluding Berlin.

Research and development (R&D) are fundamental to innovation. Measured in terms of R&D expenditure and employment in R&D, R&D-based innovation activities in east Germany lagged behind those in west Germany in the period from 1997 to 2017 (cf. box B 1-1).[64]

The following examines in detail two types of indicators – relating on the one hand to inputs and on the other to the output or success of innovation activity (see box B 1-3 for definitions).[65] On the input side, the study examines the share of companies with continuous R&D activities, the share of innovation-active companies, and the expenditure on innovation as a percentage of turnover (innovation intensity). The measures used to determine the output or success of innovation are the share of companies that have introduced at least one product or process innovation (innovator rate), and the share of turnover

Box B 1-1

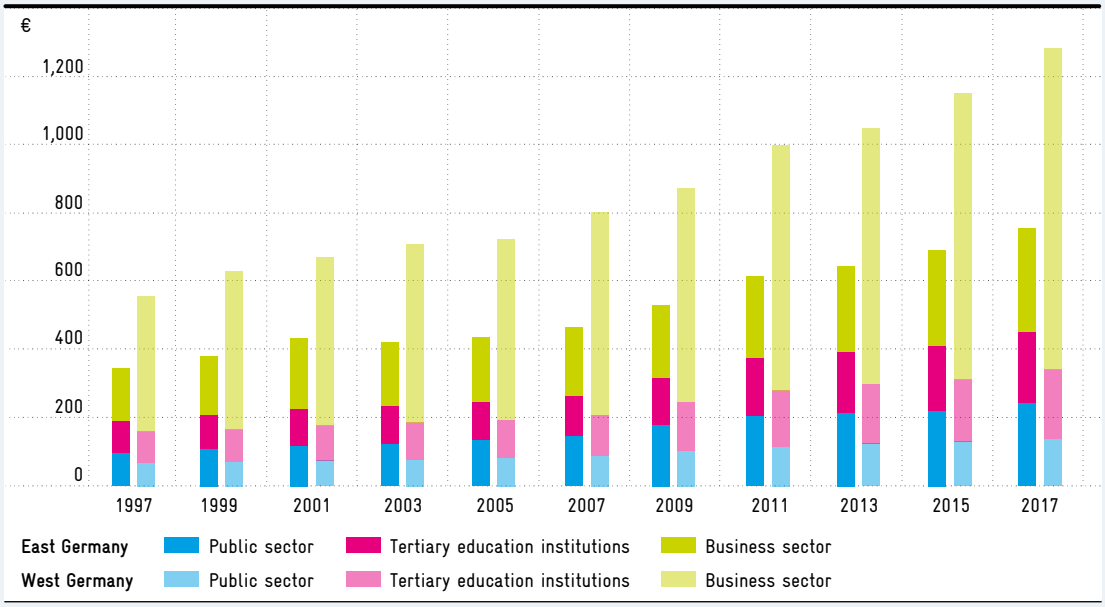
R&D in east Germany[66]

Per capita R&D expenditure more than doubled between 1997 and 2017 in east Germany, rising from €353 to €768 (cf. figure B 1-2). At €1,305 in 2017, Berlin had by far the highest per capita expenditure on R&D in east Germany. R&D employment in east Germany increased by almost 30 percent between 1997 and 2017 to around 104,000 full-time equivalents. At the same time, R&D expenditure per capita and employment in R&D have increased more strongly in the public sector than in the business sector since 1997.[67] In west Germany, R&D expenditure per capita and R&D employment have increased even more strongly overall than in east Germany over the last 20 years.[68] This was mainly due to a large amount of growth in R&D activities in the business sector (cf. figure B 1-2).[69]

Fig. B 1-2

Download data

Per capita expenditure on R&D by performing sector in east and west Germany 1997–2017 in €



Source: SV Wissenschaftsstatistik, Statistisches Bundesamt (Federal Statistical Office). Own calculations in Ihle et al. (2020).

R&D expenditure as a percentage of gross domestic product (GDP) is called the R&D intensity. Starting from 2.1 percent in 1997, the figure for east Germany rose to 2.5 percent in 2017.[70] However, R&D intensity rose much more strongly in west Germany, from 2.2 percent in 1997 to 3.1 percent in 2017. Even so, the R&D intensity of 2.5 percent achieved by east Germany in 2017 was still higher than that of e.g. France, Italy or the UK.[71]

Whereas in 2017, around 73 percent of R&D expenditure in west Germany was in the business sector, in east Germany it was only around 40 percent. In east Germany, by contrast, an important role is played in R&D financing by the public sector (state research institutions and tertiary education institutions). For example, in 2017 the state (including private non-profit institutions) contributed 33 percent of R&D expenditure in east Germany, tertiary education institutions 27 percent.[72]

Since the mid-1990s, around 30 percent of total government R&D expenditure (including private non-profit institutions) has been flowing to east Germany.[73] This amounted to more than four billion euros in 2017. The highest grants in absolute terms went to the Länder Berlin (€1.6 billion), Saxony (€1.0 billion) and Brandenburg (€0.5 billion).[74]

from product innovations – differentiated according to market novelties and imitative innovations.[75]

In order to take into account the differences in the economic structure between east and west Germany and thus arrive at a meaningful comparison, these indicators are also considered in a structurally adjusted manner: a 'matching' approach is used to identify those differences in innovation activities between east and west German companies that are not attributable to regional differences in the observable structural features.[76] The analysis adjusts for the following observable structural features: size of the companies, sector in which the companies operate, age of the companies, membership of a corporate group, and the spatial type in which companies are located. As a result, only companies in east and west Germany are compared with comparable structural characteristics.[77]

Box B 1-3

Innovation indicators[78]

Input indicators of innovation activity

Share of companies with continuous R&D activities: R&D activities carried out by the companies themselves, i.e. internal R&D activities, can be continuous or occasional. While continuous R&D activities are conducted on a permanent basis, occasional R&D activities are conducted only if needed. The share of companies with continuous R&D activities is defined as the number of companies that continuously conduct R&D activities internally as a percentage of all companies.

Share of innovation-active companies: The share of innovation-active companies indicates the number of companies that have conducted innovation activities in the preceding three-year period as a percentage of all companies. Innovation activities are defined as activities aiming at developing or introducing new or improved products or processes. These activities include internal R&D activities, external R&D activities (outsourcing of R&D contracts to third parties) and other innovation-related activities (e.g. the design or installation of new equipment).

Innovation intensity: Innovation intensity is defined as innovation expenditure relative to a company's turnover in a corresponding year. Innovation expenditure includes all R&D expenditure (internal plus external) and other internal and external expenditure necessary to implement innovation projects. This includes, for example, conceptual work, production preparation, market research and marketing concepts, further training and the acquisition of fixed assets for innovation.

Output indicators of innovation activity

Innovator rate: The innovator rate measures the number of companies that have introduced at least one product innovation (i.e. a new or significantly improved product) or process innovation (i.e. a new or significantly improved process) in the preceding three-year period as a percentage of all companies.

Share of turnover from product innovations: The share of turnover from product innovations indicates the percentage contributed by product innovations to turnover in the first three years after their market launch.

Share of turnover from market novelties: Market novelties are product innovations that companies are the first to introduce to the market. The share of turnover from market novelties indicates the percentage contributed by market novelties to turnover in the first three years after their market launch.

Share of turnover from imitative innovations: Imitative innovations are product innovations that are new to a company but not new to the market. The share of turnover from imitative innovations indicates the percentage contributed by imitative innovations to turnover in the first three years after their market launch.

Convergence in innovation inputs

The share of companies with continuous R&D activities, the share of innovation-active companies, and the intensity of investment in innovation activities provide an initial impression of the innovative performance of the business sector.

Over the last 20 years, the share of companies with continuous R&D activities was on average 1.4 percentage points higher in east Germany than in west Germany. However, there has recently been some convergence: in 2017, 11.4 percent[79] of east German and 11.1 percent of west German companies were engaged in continuous R&D activities.[80]

A comparison of structurally similar companies shows that the share of companies with continuous R&D activities in east Germany has been only slightly higher than in west Germany on average over the last 20 years (see figure B 1-4). Since 2012, the structurally adjusted share of companies with continuous R&D activities has always been below the west German level.[81]

In order to measure the willingness of the business sector to search for innovative ideas and solutions, one can consider not only companies with continuous R&D activities, but also companies that carry out R&D occasionally or engage in innovation activities without internal R&D. The number of these so-called innovation-active companies as a percentage of all companies has decreased in both east and west Germany over the last two decades – in east Germany from around 59 percent in 1999 to only 40 percent in 2017, and in west Germany, from approximately 62 percent to 44 percent over the same period. Taking the average for the period 1999 to 2017, the share of innovation-active companies in east Germany was about 5 percentage points below the west German figure.[82]

Even when the analysis takes structural differences into account, the share of innovation-active east German companies remains below that of west German companies (see figure B 1-4). This is mainly due to the lower share of innovation-active companies that only engage in R&D activity occasionally.[83]

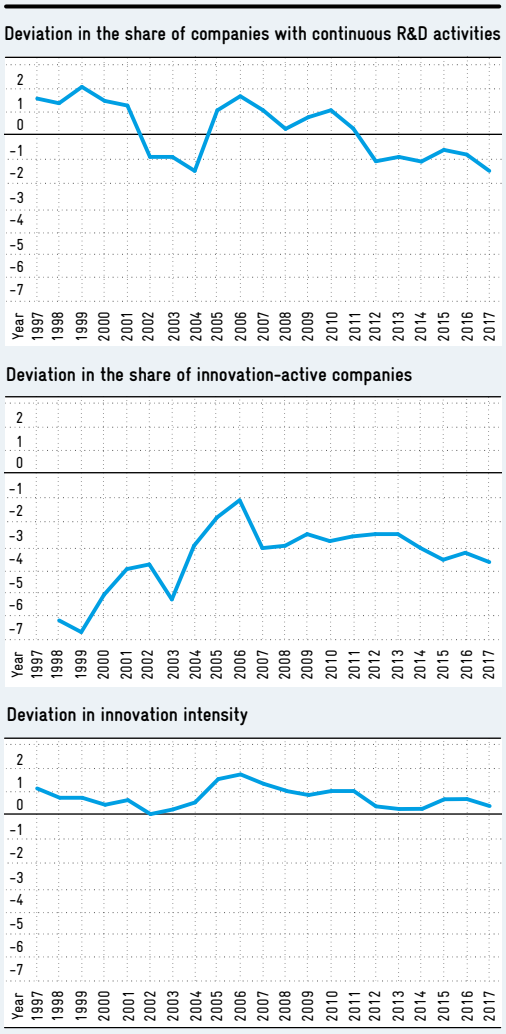
The indicator innovation intensity goes beyond the mere willingness to pursue innovation activities, and reports the intensity with which companies invest their turnover in R&D and other innovation activities. Looking at the figures that have not been structurally adjusted, innovation intensity in west Germany has remained stable over the last two decades, while it has fluctuated in east Germany. Up until 2008 it was higher than the innovation intensity of west German companies; since 2009 it has been lower. According to current figures, innovation intensity is 2.9 percent in east Germany and 3.6 percent in west Germany.[84]

Fig. B 1-4

Download data

Structurally adjusted deviation of innovation input indicators 1997–2017 in percentage points

Deviation of companies in east Germany compared to companies in west Germany



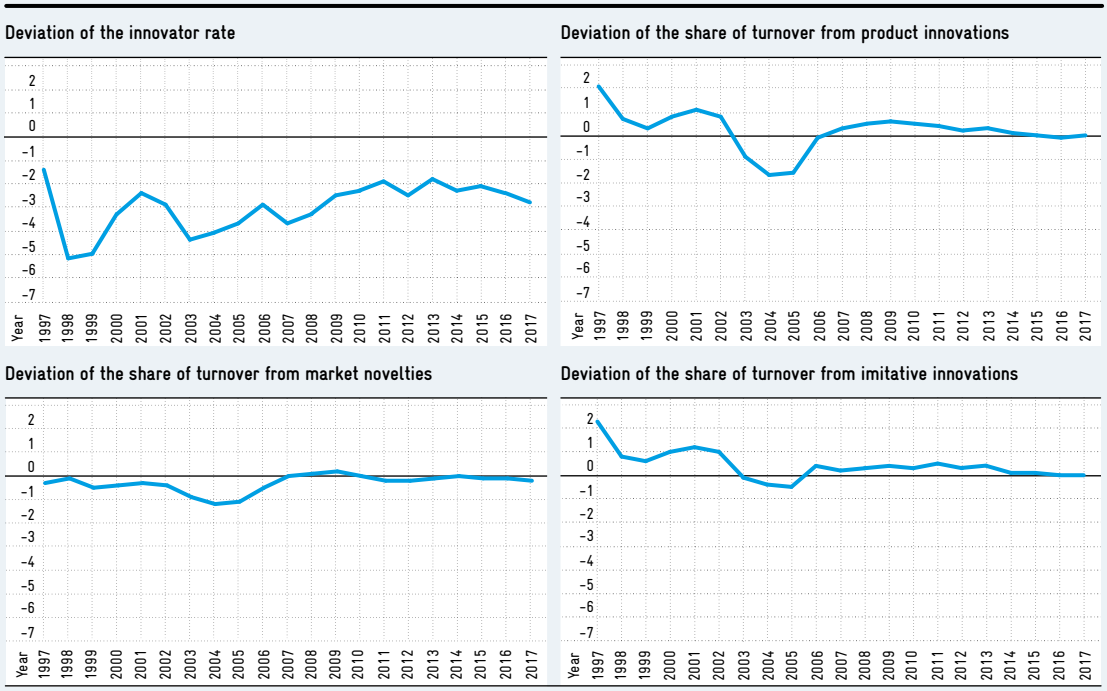
Moving averages of the previous three years. Legend: In 2017, the share of companies with continuous R&D activities in east Germany was 1.5 percentage points lower than that of structurally similar companies in west Germany.
Source: Mannheim Innovation Panel. ZEW calculations in Rammer et al. (2020b).

Fig. B 1-5

Download data

Structurally adjusted deviation of innovation output indicators 1997–2017 in percentage points

Deviation of companies in east Germany compared to companies in west Germany



Moving averages of the previous three years. Legend: In 2017, the innovator rate of companies in east Germany was 2.8 percentage points lower than that of structurally similar companies in west Germany.
Source: Mannheim Innovation Panel. ZEW calculations in Rammer et al. (2020b).

If the figures for innovation intensity are structurally adjusted, the east German companies show an average intensity of investment in innovation activities that is 0.7 percentage points higher than that of west German companies between 1997 and 2017 (see figure B 1-4). However, the current figures show hardly any differences.[85]

Mixed picture when it comes to innovation output

The market launch of new products and services and the introduction of newly developed production and manufacturing processes are an important early indicator for innovation output. The number of companies who launch new products and services and/or introduce new processes as a percentage of all companies is called the innovator rate. Between 1998 and 2017, the innovator rate in east Germany was on average about four percentage points below the rate in west Germany. As in other European countries, it has declined sharply in both east and west Germany over the last two decades:[86] from 57 percent in east Germany and 60 percent in west Germany in 1998 to only 34 and 36 percent respectively now.[87]

Also after structural adjustment, the innovator rate in east Germany is markedly lower than in west Germany (see figure B 1-5). Although the two rates initially converged somewhat over the period under consideration, this process has stagnated since the early 2010s.[88] In 2017, the innovator rate of east German companies was around three percentage points lower than in comparable west German companies.

In addition to the innovator rate, another important output measure is the share of turnover that companies have generated with innovations. The focus here is on the share of turnover from product innovations as a whole, as well as differentiated according to market novelties and imitative innovations. These three indicators developed largely parallel in east and west Germany: after a declining trend up until the mid-2010s, they tended to rise slightly again. For all three indicators, east Germany lagged behind west Germany in the period under consideration.[89]

After adjustment for structural differences, east German companies had a higher share of turnover from product innovations and imitative innovations than west German companies in the late 1990s and early 2000s (see figure B 1-5). By contrast, the share of turnover from market novelties was higher among west German companies during this period. Since the mid-2000s, however, hardly any differences can be observed in the three indicators between east and west German companies.[90]

Differences in innovation activity determined by regional structure

Innovation activities differ not only between east and west Germany, but also according to spatial structures and areas. One way of classifying areas is to divide them into settlement types according to the definition of the Federal Institute for Research on Building, Urban Affairs and Spatial Development (Bundesinstitut für Bau-, Stadt- und Raumforschung, BBSR): predominantly urban regions, partly urban regions and rural regions.[91] According to this classification, east Germany is much more rural than west Germany.[92] There are systematic differences between these three settlement types when it comes to corporate innovation activities over the period from 1992 to 2017, even when differences caused by age, size and sector are taken into account. The differences between rural and urban regions are more pronounced in east than in west Germany.[93] For example, the innovator rate in east Germany is 3.9 percentage points higher in urban regions than in rural regions. In west Germany this difference is only 3.1 percentage points.

A comparison between the innovation activities of east and west German companies located in the same settlement type does not suggest a uniform picture.

In rural regions, there is little difference between east and west Germany when it comes to the share of companies with continuous R&D activities. In urban regions, by contrast, the proportion is significantly higher in east than in west Germany (two percentage points). On the other hand, the share of innovation-active east German companies is significantly lower in rural and urban regions than in their west German counterparts, namely about three percentage points respectively. The innovation intensity of east German companies in all three settlement types is significantly higher than that of their west German counterparts. The difference amounts to around two percentage points in each case.

The innovator rate, in turn, is significantly lower among east German companies in urban and rural regions than among their west German counterparts. The differences amount to two and three percentage points respectively. However, the share of turnover from product innovations is higher for east German companies in all three settlement types than for their west German counterparts. In urban regions, for example, the difference is about four percentage points, in rural regions around two percentage points. This is because east German companies are far ahead as regards the share of turnover from imitative innovations (three to four percentage points). On the other hand, east German companies are below their west German counterparts in all settlement types in terms of the share of turnover from market novelties (one to two percentage points).

Additional innovation indicators B 1–2

Patent activities still lagging behind

Patents are intellectual property rights for new technical inventions. They provide the basis for exploiting innovations on the market, while at the same time supporting the transfer of knowledge and technology between the actors in the innovation system.[94] The following section examines triadic patent applications, i.e. patents that are filed simultaneously with the European Patent Office, the Japanese Patent Office and the US Patent Office. In east Germany, the number of triadic patent applications increased by about 29 percent to 2,428 between 2001 and 2015.[95] In west Germany, the increase over the same period – starting from a higher level – was lower at 8 percent, rising to 25,319 applications.

East Germany is still a long way behind west Germany, not only in terms of the absolute number of triadic patent applications, but also when it comes to per-capita applications. The gap has also been reduced here. In 2001, triadic patent applications per 100,000 inhabitants in east Germany amounted to about 30 percent of the west German level, in 2015 to 40 percent.[96] Berlin had by far the highest figure in east Germany with 26.7 triadic patent applications per 100,000 inhabitants in 2015.[97]

R&D employee productivity measures the number of triadic patent applications per 1,000 R&D employees. It is an indicator of how successful R&D employees are in developing new, patentable ideas.

While R&D employee productivity in east Germany increased slightly on average over the entire period under consideration, it declined markedly in west Germany.[98] For example, the gap between east and west Germany narrowed from 35.8 in 2001 to 21.9 in 2015. Most recently (2015), R&D employee productivity in east Germany was 25.6. This was only about half of the west German level (47.5).

Number of start-ups in R&D-intensive industry are at the same level as in west Germany

Young companies contribute towards augmenting and modernizing the existing range of products and services, thus making an important contribution to economic growth and to maintaining both the competitiveness of a country and the local added value generated in a region.[99] From an innovation-policy perspective, start-ups are particularly important in the knowledge-intensive sectors.[100] The knowledge-intensive sectors comprise R&D-intensive industry and knowledge-intensive services.[101]

As in many other industrialized countries, the number of start-ups in the knowledge-intensive sectors declined in Germany:[102] from over 35,400 in 1997 to 21,300 in 2018. Relatively speaking, east Germany was more affected by the decline than west Germany.[103] The majority of start-ups in the knowledge-intensive sectors are active in the field of knowledge-intensive services. Over the past 20 years, the number of start-ups in this field has fallen by 45 percent in east Germany, and thus more sharply than in west Germany (37 percent).[104] A different east-west picture emerges when looking at R&D-intensive industry. While more than 2,700 companies were founded in this field in Germany in 1997, the number of start-ups in 2018 was only 1,250. In recent years, the number of start-ups in east Germany has stabilized at an average of 250 per year, while it has fallen continuously in west Germany.[105]

Start-up intensity indicates the annual number of start-ups per 10,000 employable people and is an indicator of the willingness to start a business. In line with the absolute number of start-ups, start-up intensity has also declined sharply in the knowledge-intensive sectors. Over the past 20 years, it has fallen from 5.7 to 3.7 in east Germany. This decline was somewhat less pronounced than in west Germany (from 6.9 to 4.2). Among other factors, the smaller decline in east Germany is due to start-up activities in Berlin, which are above average and stable.[106] Start-up intensity in the other east German Länder is correspondingly well below that of west Germany and has been falling almost in parallel since 2004.[107] Most recently (2018), the gap between east and west Germany halved compared to 1997.[108]

In terms of start-up intensity in knowledge-intensive services, east Germany (without Berlin) lags markedly behind west Germany and has shown a somewhat steeper decline. For example, start-up intensity in east Germany (without Berlin) was only 2.0 in 2018, a fall of 2.4 compared to the intensity level in 1997 (4.4).[109] In west Germany, the corresponding start-up intensity fell by 2.4 over the same period to 4.0 in 2018 (cf. figure B 1-6). With an average of 8.1 since 1997, Berlin (next to Hamburg) has by far the highest start-up intensity in knowledge-intensive services.

In R&D-intensive industry, start-up intensity has fallen in east and west Germany over the past 20 years from 0.40 and 0.55 respectively to both 0.24 in 2018 (see figure B 1-6). Here, too, there are large regional differences; for example, start-up intensities in Berlin, Saxony-Anhalt and Thuringia were above the west German average.[110]

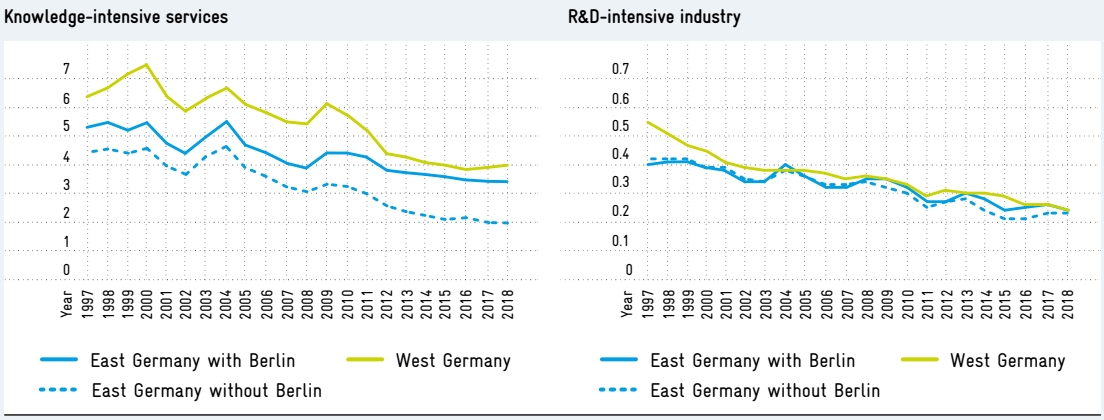
Spin-offs from tertiary education institutions make a particular contribution to the transfer of new ideas from application-oriented basic research to innovative application.[111] In 2017, there were around 460 spin-offs at east German tertiary education institutions, which corresponds to a share of over 25 percent of nationwide spin-offs.[112] While there were an average of 11.5 spin-offs per 10,000 students and graduates at east German tertiary education institutions in 2017, there were only 9.6 in west German tertiary education institutions. Tertiary education institutions in Brandenburg and Saxony-Anhalt recorded the highest figures nationwide with 22.2 and 18.4 respectively per 10,000 students and graduates.

The EXIST programme in particular has contributed to a positive development of the start-up culture at German tertiary education institutions.[113] Since 2007, with its EXIST Transfer of Research (EXIST-Forschungstransfer) programme, the Federal Ministry of Economics and Energy (Bundesministerium für Wirtschaft und Energie, BMWi) has been supporting in particular development activities which are important to prove the technical feasibility of research-based start-up ideas.[114] One third of the EXIST Transfer of Research projects were funded in east Germany.[115] Saxony, Berlin and Thuringia accounted for the largest number of projects by far.[116]

Fig. B 1–6

Download data

Start-up intensity in knowledge-intensive services and R&D-intensive industry in east Germany (with and without Berlin) and west Germany 1997–2018



Knowledge-intensive services: technology-oriented services and non-technical advisory services.
R&D-intensive industry: cutting-edge and high-value technology.
Source: Mannheim Enterprise Panel. Own calculations in Ihle et al. (2020).

The EXIST Business Start-up Grant (EXIST-Gründerstipendium) funding line supports innovative technology-based start-up projects in the seed phase.[117] In 2017, about one third of the Business Start-up grants were awarded to beneficiaries in east Germany. Nearly half of these went to students, graduates and scientists from Berlin.[118]

Small proportion of innovation cooperation is international

Cooperation with other companies and organizations, especially from science, plays an important role in companies' innovation activities. Cooperation is especially important for SMEs to make up for their limited internal innovation activities and to share innovation risks with others.[119]

Since the end of the 1990s, innovation policy in east Germany has been geared towards promoting cooperation and networks (cf. figure B 1-7), in particular to initiate or strengthen regional cooperation relations between business and science, which were more pronounced in west Germany.[120] This is also evident with regard to the types of cooperation partners and a strongly regional orientation of cooperation activities.[121]

Looking only at innovation-active companies, the last 20 years (1996–2016) reveal that their cooperation activities were more pronounced in east than in west Germany. For this group, the share of East German innovation-active companies engaged in cooperation on innovation is significantly higher than among their west German counterparts.[122] In 2016, the rate in east Germany was 26 percent, in west Germany 17 percent.

During this period, also at the sector level the proportion of innovation-active companies cooperating on innovation was higher in east than in west Germany. In east Germany, for example, this averaged over 50 percent in the R&D-intensive industry, markedly higher than the percentage among west German companies (37 percent). In knowledge-intensive services, too, considerably more east German innovation-active companies entered into innovation cooperation agreements than west German innovation-active companies (30 percent compared to 21 percent).[123]

Tertiary education institutions and non-university research institutions (außeruniversitäre Forschungseinrichtungen, AUF) are by far the cooperation partners most frequently named by innovation-active companies in both east and west Germany.[124] This percentage of innovation cooperation with non-university research institutions has risen sharply nationwide in recent years. In 2016, east and west Germany hardly differed at all here.[125]

However, differences can be found in cooperation activities between innovation-active companies and competitors. While an average of 27 percent of innovation-active companies in west Germany cooperated with a competitor in the period from 1996 to 2016, in east Germany the figure was only 23 percent.[126]

There are also differences between east and west Germany with regard to the spatial distribution of the cooperation partners. For example, east German innovation-active companies cooperate more often regionally and much less frequently at the European level.[127] This higher proportion of regional cooperation in east Germany could reflect the more regionally oriented cooperation funding in east Germany in recent years. A more international orientation could, however, expand the innovation-related scope of possibilities.

B 1-3 R&I funding in east Germany

Over the past 30 years, the Federal Government has invested considerably in the R&I system in east Germany.[128] For example, the Federal Government's R&D expenditure in the east German Länder and Berlin totalled €68.5 billion between 1991 and 2018.[129] That is the equivalent of about 23 percent of the Federal Government's total R&D expenditure.

With the Solidarity Pact II (Solidarpakt II), the Federal Government provided the east German Länder and Berlin with a total of around €10.6 billion in what is known as disproportionate funding[130] for the policy area of 'Innovation, R&D, Education' in the period from 2005 to 2018.[131]

The priorities and measures of the Federal Government's R&I funding for the east German economy have changed over the years. In the early 1990s, R&I policy programmes were primarily designed to offset falling R&D staff levels. From the mid-1990s onwards, project funding became more important, with cooperative and collaborative projects gaining in importance (cf. figure B 1-7).[132] This funding then expanded further in the direction of a regionally oriented innovation policy to promote the innovation potential of entire regions. Following the general trend in European innovation policy, after the turn of the millennium the Federal Government promoted networks – i.e. long-term cooperation between different actors in research and innovation.

High proportion of subsidized companies in east Germany

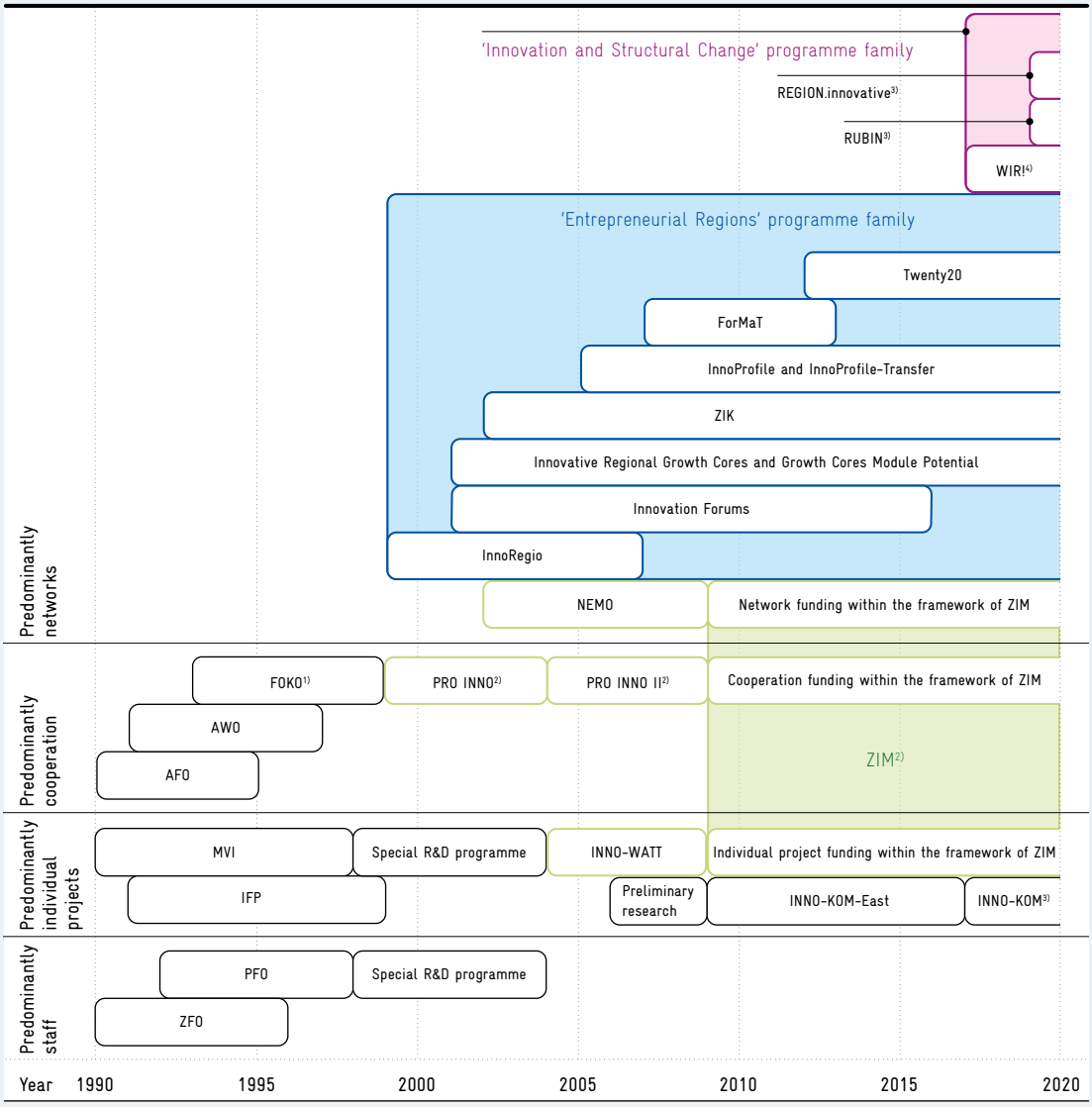
Public innovation funding is much more widespread in east Germany than in west Germany. In 2016, 26 percent of east German and 15 percent of west German innovation-active companies received financial support.[133] The focus of R&I programmes on the promotion of R&D activities is reflected in a higher proportion of funded companies in the R&D-intensive industry than in other industrial sectors (2016: 59 vs. 27 percent in east Germany, 31 vs. 14 percent in west Germany). Differentiated according to R&D activity, the percentage of companies receiving funding was highest among companies with continuous R&D activities, whereas innovation-active companies without internal R&D hardly benefited from funding at all (2016: 57 vs. 9 percent in east Germany, 31 vs. 8 percent in west Germany).[134] Companies that generate innovations without internal R&D tend to be smaller companies in non-research-intensive or non-knowledge-intensive sectors with a low proportion of highly qualified employees and a low export orientation.[135] Similarly, the funding provided by the Central Innovation Programme for SMEs (Zentrales Innovationsprogramm Mittelstand, ZIM) predominantly reaches more R&D-experienced companies;[136] this is particularly true for east Germany.[137] Another focus of R&I policy programmes in east Germany is the promotion of regional alliances (cf. figure B 1-7). This applies in particular to the initiatives within the 'Entrepreneurial Regions' (Unternehmen Region) programme family, including InnoRegio, Innovative Regional Growth Cores (Innovative Regionale Wachstumskerne) and InnoProfile Transfer (InnoProfile-Transfer).[138]

In general, no comprehensive statements can be made about the effects of these support measures. There is a lack of a systematic evaluation that takes into account the interplay of the programmes of several funding authorities. Existing evaluation studies confirm that the R&I programmes financed within the framework of Solidarity Pact II have had predominantly positive promotional effects, especially with regard to R&D activities, employment and turnover figures, and the formation of collaborations and networks of the companies that received funding.[139] There are, however, indications that in individual cases the expected implementation success of the projects was not yet fully achieved by the end of the funding period, e.g. Team Research for the Market (Forschung für den Markt im Team, ForMaT), Centres for Innovation

Federal R&D funding programmes (BMBF and BMWi) in the east German economy (with Berlin) 1990–2019

Fig. B 1-7

Download data



1) Nationwide programme with an east-specific sub-programme called 'R&D Joint Projects East' (FUEGO).
2) Nationwide programmes with preferential support for east Germany. Disproportionate funds under Solidarity Pact II.
3) Funding in structurally weak regions. INNO-KOM: disproportionate funds under Solidarity Pact II.
4) Since 2019, funding in structurally weak regions.

Not included are start-up funding programmes and the programmes 'External Innovation Management for Small Enterprises in the New Länder' (InnoMan) and 'Business Meets Science'. Another nationwide predecessor programme of ZIM without special regulations for east German grant recipients is 'Promotion of Innovative Networks' (InnoNet).

Staff development: ZFO: R&D Personnel Growth Promotion East; PFO: R&D Personnel Funding East; Special R&D Programme: funding of research, development and innovation in small and medium-sized enterprises and external industrial research institutions in the new Länder. Individual project funding: MVI: industrial research to prepare the market; IFP: innovation support programme; INNO-WATT: promotion of research and development among growth drivers in disadvantaged regions; Preliminary research: funding of preliminary industrial research in disadvantaged regions; ZIM: Central Innovation Programme for Small and Medium-Sized Enterprises; INNO-KOM-East: R&D support for non-profit external industrial research institutions in east Germany (Innovation Competence East); INNO-KOM: R&D support for non-profit external industrial research institutions (Innovation Competence). Cooperation funding: AFO: Contract and Development Research East; AWO: Contract Research West-East; FOKO: Research Cooperation in SMEs; PRO INNO: Innovation Competence of SMEs; PRO INNO II: funding to promote the innovation competence of SMEs. Network funding: NEMO: Network Management East; ZIK: Centres for Innovation Competence: creating excellence – securing talent; ForMaT: Team Research for the Market; Twenty20: Twenty20 – Partnership for Innovation; WIR!: WIR! – Change through Innovation in the Region; RUBIN: RUBIN – Regional Entrepreneurial Alliances for Innovation.

Source: own diagram based on Günther et al. (2010). Cf. also Ihle et al. (2020).

Competence (Zentren für Innovationskompetenz, ZIK).[140] While in the evaluation of ZIM control group analyses were also carried out, previous evaluation studies have largely been based only on corporate surveys, assessments by the grant recipients, and the development of economic indicators in terms of the subsidized companies.[141] A comprehensive impact analysis of the measures and their effects in relation to different success factors has so far not been carried out for most funding programmes.

New national funding system for structurally weak regions

Following the expiry of Solidarity Pact II in 2019, the Federal Government has been supporting structurally weak regions at the national level since the beginning of this year,[142] regardless of whether they are in east or west Germany, urban or rural. The adopted structural-policy measures developed by the commission on 'Equal Living Conditions' include, among others, programmes to boost innovation, improve the technical and social infrastructure, and ensure the supply of skilled manpower.[143]

The national funding system for structurally weak regions, bundles, inter alia, several federal programmes and programme families in the field of 'Research and Innovation'.[144] First, there are programmes that provide funding exclusively in structurally weak regions: the 'Entrepreneurial Regions' programme family, the 'Innovation and Structural Change' (Innovation und Strukturwandel) programme family developed from it, and Innovation Competence (Innovationskompetenz, INNO-KOM). Second, there are programmes that are not restricted to the structurally weak regions of the funding system, but contain funding preferences for these regions, e.g. increased funding rates or reduced conditions on own contributions: ZIM and Innovative Municipalities (Kommunen innovativ). And third, programmes are included which are also not limited to structurally weak regions, but which, due to their objectives and the regional differences in the distribution of problems, lead to a disproportionate use of funds in structurally weak regions: EXIST-Potentials (EXIST Potentiale).[145]

Recommendations B 1-4

Even 30 years after reunification, there are still major structural differences between east and west Germany which impact inter alia on corporate innovation activities. A comparison of structurally similar companies shows that the level of innovation activity in east German companies has converged with that of west German companies in recent years. However, there is still a need for east German companies to catch up when it comes to launching innovation activities and introducing innovations to the market.

Within both east and west Germany there are differences in innovation activities between companies in rural and urban regions. These are more pronounced in the east than in the west.

Start-up intensity in the knowledge-intensive sectors has been declining for years in east and west Germany. In the meantime there is no longer any difference between east and west Germany in R&D-intensive industry. However, in knowledge-intensive services, start-up intensity in east Germany is still lower than in west Germany.

East German companies cooperate more on their innovation projects than west German companies, whereby their cooperation activities are more frequently regionally oriented.

Gear R&I policy for structurally weak regions towards excellence criteria

- Against the background of the convergence of innovation activities of east and west German companies according to key indicators, the Commission of Experts welcomes the fact that the Federal Government will refrain from providing special R&I support for east German companies after the expiry of Solidarity Pact II. One important task of the Federal Government's R&I policy is to strengthen Germany's position in global competition. The Commission of Experts therefore believes that R&I policy should continue to focus on promoting excellent innovation projects, which exist in both east and west Germany.
- In the Commission of Experts' view, it makes sense to support R&I in structurally weak regions chosen on the basis of regional characteristics and not according to the borders between Länder.

Such funding, too, should target projects chosen according to excellence criteria. The national funding system for structurally weak regions introduced at the beginning of the year already contains corresponding funding formats.

– Furthermore, the Commission of Experts advocates an innovation-oriented structural policy. This promotes the potential of structurally weak regions, for example through infrastructure measures, and in this way aims to increase their overall willingness and ability to innovate. Examples include measures under the planned law for the structural strengthening of coal regions (Strukturstärkungsgesetz Kohleregionen), programmes for fields such as broadband network expansion and digitalization in the national funding system for structurally weak regions, and measures under the 'Joint Task for the Improvement of Regional Economic Structure' (Gemeinschaftsaufgabe Verbesserung der regionalen Wirtschaftsstruktur, GRW).[146] The Commission of Experts urges a rapid, effective and coordinated implementation of such programmes.

Motivate more companies to innovate

– The Federal Government's R&I funding currently focuses on the promotion of R&D activities. In order to motivate more companies in structurally weak regions to engage in innovation activities, companies without R&D should be integrated more closely into R&I funding. In other words, non-technical and social innovations should also be given more support. This can be done on the one hand by opening up existing programmes and, on the other, by introducing specific programmes for innovation projects not involving R&D.[147]

Support the market launch of innovations

– The Commission of Experts recommends that in future R&I policy should be more oriented towards giving companies in structurally weak regions support in launching new products and services onto the market, thus increasing the innovator rate. This applies particularly to SMEs. The promotion of innovation advisory services and innovation support activities should therefore be increased.

Support start-ups from the scientific community

– The Commission of Experts welcomes the fact that the EXIST-Potentials programme supports in particular small and medium-sized tertiary education institutions in their entrepreneurship activities and that the total funding for EXIST is being increased. In order to promote academic start-ups, the culture of entrepreneurship and start-up training at tertiary education institutions should be further strengthened.

Create incentives for supra-regional and international cooperation

– The Commission of Experts attaches importance to regional networking among innovation actors. However, it suggests placing greater emphasis on supra-regional and international forms of cooperation and networking in R&I funding.

Improve accompanying research on R&I funding programmes

– The Commission of Experts once again urges that accompanying research on R&I funding programmes should be geared towards their impact. The prerequisites for this are an ex-ante definition of parameters for targets and measurement and a comprehensive database on important characteristics of funded and non-funded applicants and the selection process.

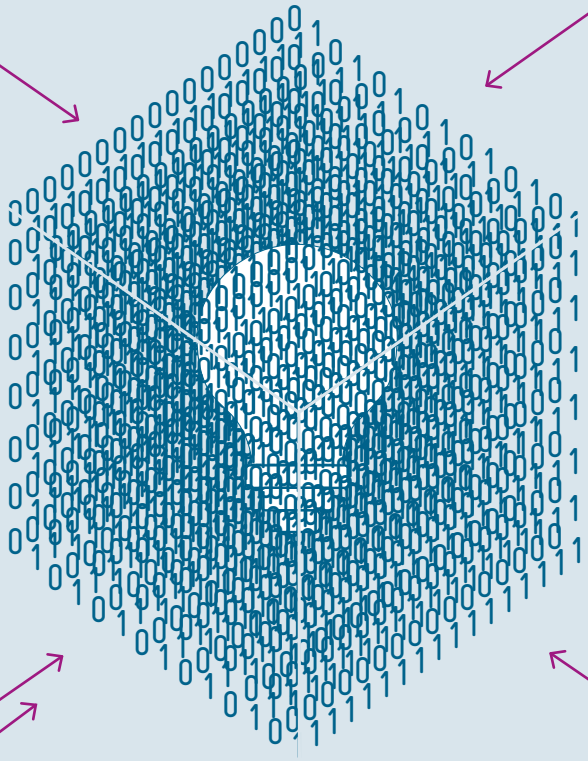
B 2 Cybersecurity

Download data

Ongoing digitalization and connectivity make companies more vulnerable to cyberattacks. Corporate innovation activities are directly affected by this threat.

Malware performs unwanted or harmful functions on a computer system.

Ransomware is used by attackers to encrypt the data in an IT system to prevail upon users to pay a ransom.

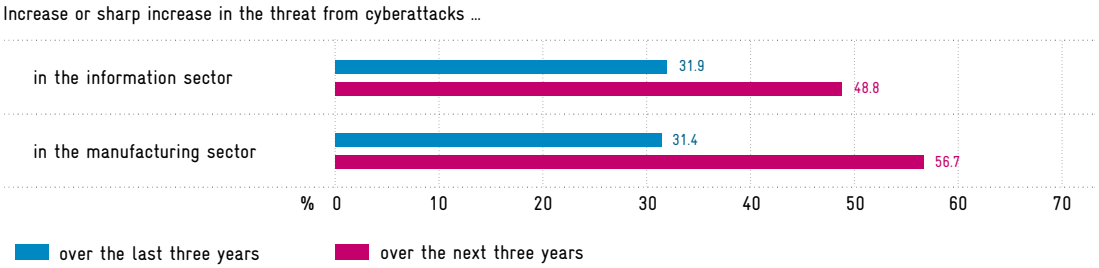


Advanced persistent threats have a high threat potential because the attackers find weaknesses in a targeted and persistent manner in order to exploit them.

Social engineering manipulates people to persuade them to disclose confidential information, open files or links with stored malware, or transfer money to unauthorized recipients.

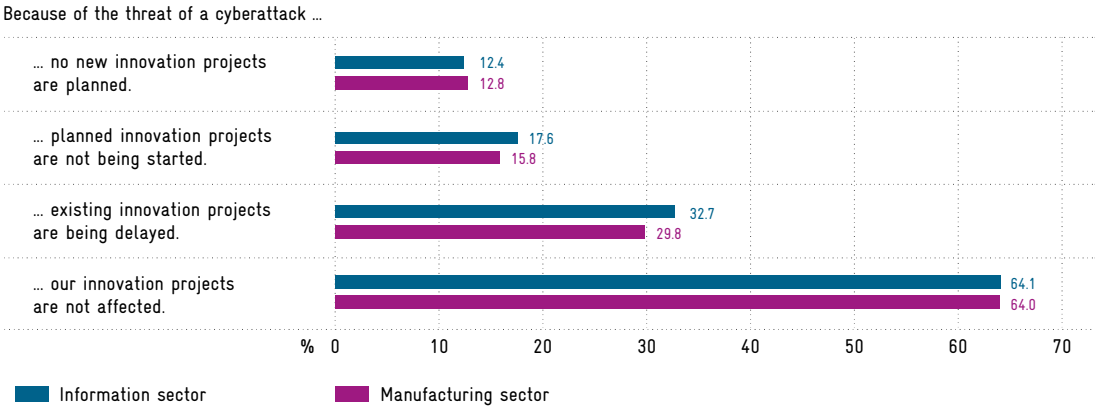
DDoS attacks cause network services to fail after they have been overloaded and thus blocked by a huge number of requests.

Assessments by companies on the development of the threat from cyberattacks[1)]



Sector-specific extrapolation of results to the question: "How do you assess the change in cyberattack exposure for your company?" Legend: 56.7 percent of manufacturing companies expect the threat of cyberattacks to increase or rise sharply over the next three years.

Impact of cyber threats on innovation activities[2)]



Sector-specific extrapolation of results to the question: "What impact is the threat of a cyberattack having on your company's innovation activities?". Multiple answers possible. Legend: 12.8 percent of manufacturing companies are not planning any new innovation projects because of the threat of a cyberattack.

See chapter D 7 for a list of sources of infocharts.

B 2 Cybersecurity

Ongoing digitalization and connectivity make innovative companies more vulnerable to cyberattacks. The majority of innovative German companies in the information and manufacturing sectors are therefore quite aware of the need to protect the information technology (IT) they need for innovation activities.[148] In addition, more than half of these innovative companies expect the threat posed to their business by cyberattacks to grow further in the coming years.[149] Corporate innovation activities are directly affected by this risk (cf. figure B 2-2).[150] As a result, cyberattacks have an indirect negative impact on Germany's economic growth. This applies in particular to the contribution to growth made by future digital technologies such as artificial intelligence or the Internet of Things, because the success of these technologies partly depends on their security.

Cybersecurity in turn is itself the subject of innovation, and its products and services contribute directly to economic growth and prosperity in Germany. The gross value added of the German IT security industry amounted to €15.5 billion in 2017, accounting for 14.3 percent of the total IT industry with its gross value added of €108.6 billion – compared to 12.9 percent in 2010. Gross value added in the IT security industry grew nominally by an average of 5.6 percent per year from 2010 to 2017. By contrast, the average nominal growth of the overall IT sector and the economy as a whole was lower, amounting to 4.3 percent and 3.4 percent per annum respectively in the same period.[151]

In addition, cybersecurity has an important role to play in maintaining critical infrastructures (CIs). CIs are found in the sectors of energy, information technology and telecommunications, water, food, health, finance and insurance, transport and traffic.[152]

However, an increase in cybersecurity – and thus an increase in German corporate innovation activities – faces a number of obstacles stemming, among other things, from the characteristics of cybersecurity. Typically, cybersecurity has the characteristics of a public good with the associated external effects. Individual actors invest too little in cybersecurity because they do not take into account the positive effects for other actors. In addition, users of IT products such as hardware or software have only limited insight into the level of security made available by providers. Furthermore, it is often difficult for companies to quantify the risk of a cyberattack and assess the resulting damage.

At present, both the private and the public sectors are keen to recruit cybersecurity experts. Yet corresponding positions remain vacant for quite long periods of time. Smaller companies in particular, which are less likely to have cybersecurity experts in their workforce, are therefore finding it difficult to utilize external offers of information on cyber threats and their prevention, and to implement protective measures.

Cybersecurity and innovations B 2–1

Different kinds of cyber threat

According to the Federal Office for Information Security (Bundesamt für Sicherheit in der Informationstechnologie, BSI, cf. box B 2-1), cybersecurity involves all aspects of security in information and communication technology (ICT).[153] The term cybersecurity has a broader definition than the term IT security. "The field of action of classic IT security is extended to include the whole of cyberspace. This covers all information technology that is connected to the internet and comparable

networks and includes communications, applications, processes and processed information based on it."[154] A cyberattack is a case of unauthorized access to IT systems with the aim of provoking a data leak or malfunction. Such an attack on IT systems uses resources of information technology itself.[155]

Because of the abundance of different hardware and software products, there is also a multitude of methods for gaining unauthorized access to IT systems. In its latest status report, the BSI analyses the attack methods it has observed. These include identity theft, malware, ransomware, distributed denial of service (DDoS), botnets, spam, advanced persistent threat attacks (APT attacks) and attacks exploiting modern processor architecture (cf. box B 2-2).

Malware attacks are the most common type of attack with a share of 53 percent, followed by DDoS attacks (18 percent) and APT attacks (12 percent).[156]

Box B 2-1

Federal Office for Information Security (Bundesamt für Sicherheit in der Informationstechnik, BSI)[157]

The BSI is part of the Federal Ministry of the Interior, Building and Community (BMI). It deals with all aspects relating to IT security with the aim of enabling and promoting the secure use of information and communication technology.

In addition to the BSI's official seat in Bonn, there are so-called contact persons in six other cities. These are central contact points for Länder and local authorities, Federal and EU authorities in the respective regions, companies, think tanks and decision-makers in society. Furthermore, the National Cyber Defence Centre (Nationales Cyber-Abwehrzentrum, Cyber-AZ) is located at the BSI. Its remit is to optimize operational cooperation between different government bodies and to co-ordinate their activities. Members of the Cyber-AZ include, for example, the Federal Police and the secret services.

The 'Act to Strengthen the Security of Federal Information Technology' (BSI Act) defines the tasks of the BSI. Its purpose is to draw attention to the topic of IT security in administration, business and society and to support these institutions in implementing IT security on their own authority. This takes the form of formulating minimum standards for Federal IT and recommendations for action for companies and citizens. The BSI is also responsible for protecting the computers and networks of the federal administration. The BSI reports once a year to the Committee on Internal Affairs of the German Bundestag on these issues.

The tasks of the BSI also include (i) the testing, certification and accreditation of IT products and services, (ii) warning against malware or security gaps in IT products and services, (iii) providing IT security advice to the federal administration and other target groups, (iv) informing and sensitizing citizens to the topic of IT and internet security, (v) the development of uniform and binding IT security standards, and (vi) the development of cryptosystems for the Federal Government's IT.

The act implementing the 'EU Directive concerning measures for a high common level of security of network and information systems' (NIS Directive)[158] also created new powers for the BSI in 2017. On the one hand, the BSI's supervisory and enforcement powers vis-à-vis operators of CI were extended, and new powers were created vis-à-vis providers of digital services. On the other hand, cooperation between the Länder and the BSI was strengthened, enabling the BSI to provide the Länder with even more comprehensive support and technical expertise.[159]

Box B 2-2

Current attack methods according to BSI status report[160]

The following description illustrates relevant methods of attack. Some of them overlap and can be combined, e.g. in a multi-stage attack.

Identity theft is a phenomenon that is highly relevant for online business. A specific login is often required to use online services such as social networks, streaming portals, online shops or booking sites. The user is identified to the provider via individual login data. If these login data are stolen, unauthorized persons can gain extensive insight into the user's private sphere and misuse this information. In 2013, for example, an attack succeeded in stealing the names, email addresses and passwords of three billion Yahoo customers.[161] Over a period of five years, the Marriott hotel chain was exposed to unauthorized access to customer data, resulting in the theft of the names, passport numbers and credit card data of about 500 million customers.[162] Identity theft data can be used to gain information for other types of attacks such as social engineering or credit card fraud. Stolen data sets are often sold on online marketplaces. It is possible to check online whether one's login data have been stolen and published.[163]

Malware comprises all types of computer programs that can perform unwanted or harmful functions on a computer system.[164] As reported by the BSI, the IT-security company AV-TEST recorded about 114 million malware variants in the last BSI reporting period between 1 June 2018 and 31 May 2019. This corresponds to approximately 312,000 malware activities daily.[165] According to the BSI cybersecurity survey, 53 percent of the reported attacks used malware.[166] In addition, attacks with malware are among the ten biggest threats to systems for manufacturing and process automation (industrial control systems).[167]

Ransomware is used by an attacker to encrypt the data in an IT system to prevail upon users to pay a ransom. However, the payment of ransoms in the past has not always resulted in the perpetrators decrypting the data again. There are no aggregated figures on damage levels. Nevertheless, individual cases of damage illustrate the damage potential of ransomware attacks. For example, a Norwegian aluminium company reported a ransomware attack in March 2019 and after only a week it had already recorded losses of about €40 million. As recommended by the BSI, the company did not pay a ransom, but restored its data from backups.

IT systems can also be disrupted by so-called **DDoS** (Distributed Denial of Service) **attacks**. These attacks cause network services to fail after they have been overloaded by a large number of requests and thus blocked. Such services include, for example, email

Cyber risks as a threat to innovation activities

Cyberattacks can serve various purposes that impact on companies both in general and in relation to their innovation activities. A distinction is made between attacks on confidentiality, integrity and availability.[170]

In attacks on confidentiality, perpetrators try to spy on confidential information, for example by wiretapping a radio network or recovering deleted information. Attacks on integrity can be manipulations of e.g. information, software or interfaces. In attacks on availability, perpetrators aim to sabotage information or IT services, for example by launching DDoS attacks.

Cyberattacks reduce the potential revenues and increase the potential costs of innovation activities. This in turn reduces the returns from these activities and the incentives for R&D. While the cyber-protection of innovation activities entails costs, it increases the incentives for R&D to the extent that the additional revenues from the protected innovation activities cover the additional costs of cybersecurity.

A representative survey[171] conducted on behalf of the Commission of Experts shows how the threat of cyberattacks can affect corporate innovation activities. 64 percent of both companies in the information sector[172] and companies in the manufacturing sector[173] do not believe that the danger

services or corporate websites. DDoS attacks are the second most common type of attack, accounting for 18 percent of all reported attacks, according to the BSI cybersecurity survey.[168] For an estimate of the damage, the BSI refers to the company Netscout, which has calculated total DDoS losses for German companies in 2018 of around four billion euros. Cloud servers are increasingly being rented for DDoS attacks. In the winter of 2018, 59 percent of DDoS attacks were carried out via cloud servers, compared to two percent two years earlier.

Botnets consist of a large number of networked devices such as computers, smartphones or IoT (Internet of Things) devices over which an attacker has gained control. This allows the attacker to misuse the devices for their own aims. When the motives are financial, devices can be misused for cryptocurrency mining, for example.[169] However, botnets can also be used for sabotage when implemented in DDoS attacks.

Spam is defined as unsolicited emails, sometimes containing advertising, which aim to defraud, contain malware, or seek to induce the recipient to disclose login data. The BSI has registered a 40 percent decline in spam compared to the previous reporting period. Spam containing malware has decreased by as much as 96 percent. However, the effectiveness of spam has increased considerably, so it cannot be assumed to involve less potential to cause damage. For example, there are malware programs that analyse the email traffic in an infected system and send new spam messages to contacts of the infected system by referring to the previous email traffic. Such e-mails can deceive even sensitized persons.

APT (Advanced Persistent Threat) attacks pose a particular threat. They are characterized by a high threat potential because the attackers find out weaknesses in a targeted and persistent manner in order to exploit them. The threat scenario is aggravated by the fact that gaining access to powerful tools for APT attacks has become increasingly easy.

In addition to exploiting weaknesses in software, weaknesses in hardware can also be exploited for attacks. Examples of this are attacks using modern processor architecture such as the Spectre variants, Meltdown or Foreshadow. It is unlikely that these weaknesses can be fully overcome. However, the BSI has not yet seen any indication that this method of attack has been actively exploited.

of a cyberattack influences their innovation projects (cf. figure B 2-3). Existing innovation projects are being delayed by the risk of a cyberattack in 32.7 percent of information sector companies and 29.8 percent of manufacturing companies. The figures are significantly higher among companies that expect the threat of cyberattacks to increase or sharply increase over the next three years than among companies that do not expect such an increase.[174] In 17.6 percent of companies in the information sector and 15.8 percent of manufacturing companies, planned innovation projects are not being started because of the danger of a cyberattack. In 12.4 percent of IT companies and 12.8 percent of manufacturing companies, no new innovation projects are planned because of the risk of a cyberattack.

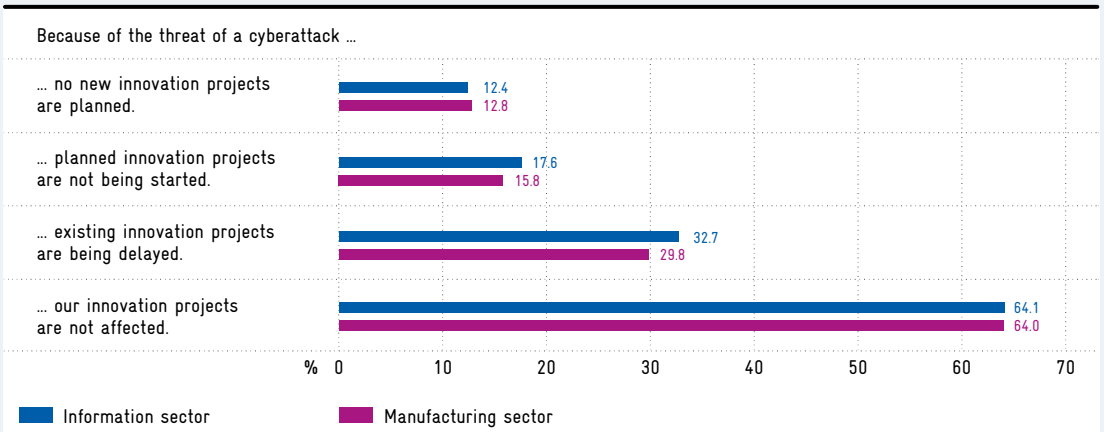
Furthermore, the survey shows that even in companies with no ongoing innovation projects, the risk of a cyberattack plays a role in the decision not to plan any new innovation projects. For example, 14.5 percent of IT companies and 16.2 percent of manufacturing companies with no ongoing innovation projects are not planning new innovation projects.

In order to minimize cyber risks, companies in the information and manufacturing sectors are focusing primarily on investing in IT security, giving the workforce further training in IT, and recruiting qualified IT staff (cf. figure B 2-4). In some cases, the degree of digitalization of innovation processes is also being reduced; in others, innovation projects are being relocated from abroad to Germany. To

Fig. B 2-3

Download data

Impact of cyber threats on innovation activities

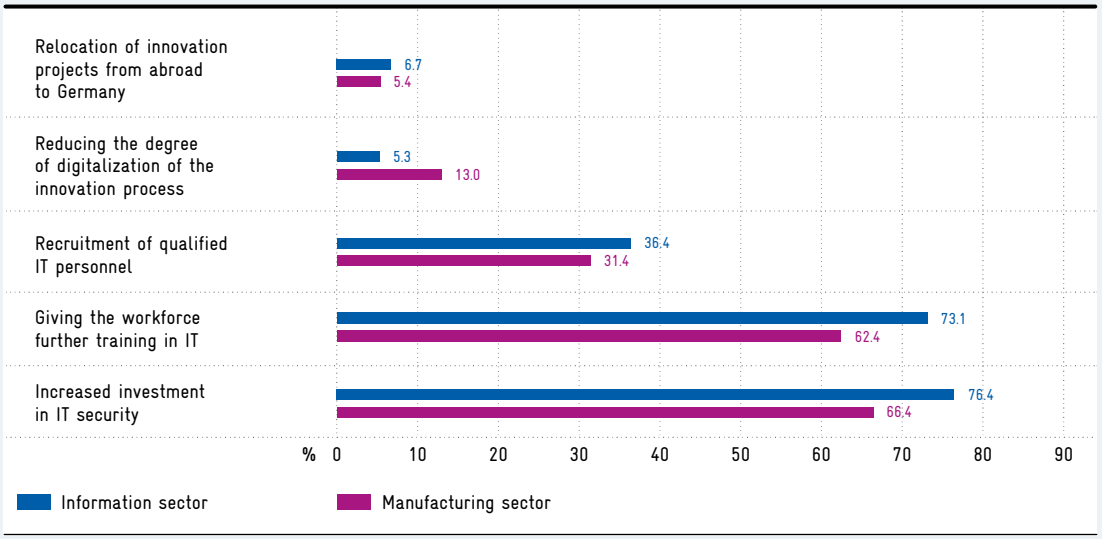


Sector-specific extrapolation of results to the question: "What impact is the threat of a cyberattack having on your company's innovation activities?". Multiple answers possible. Legend: 12.8 percent of manufacturing companies are not planning any new innovation projects because of the threat of a cyberattack.
Source: ZEW Business Survey in the Information Economy, 3rd quarter 2019. Calculations in ZEW (2020).

Fig. B 2-4

Download data

Measures taken by companies to minimize cyber risks

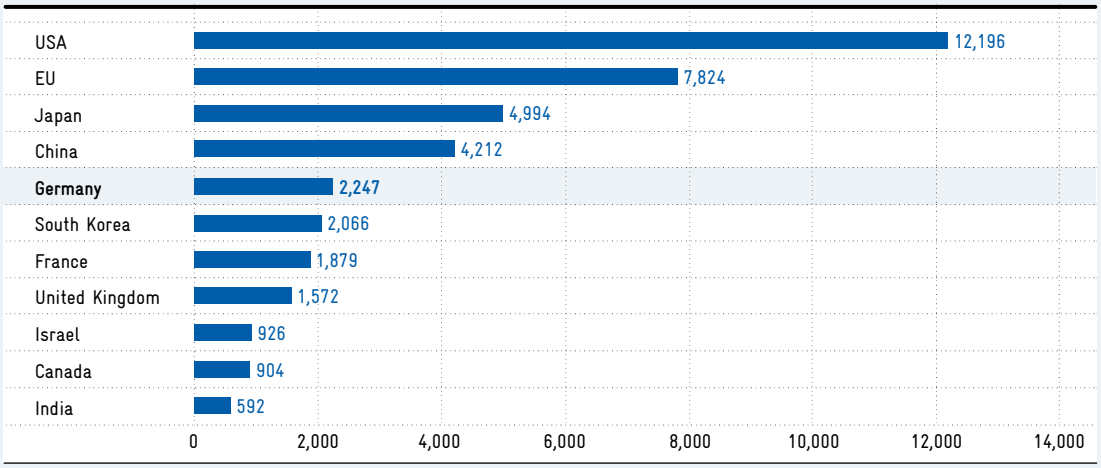


Sector-specific extrapolation of results to the question: "Are the following measures being taken in your company to minimize cyber risks?". Multiple answers possible. Legend: 13.0 percent of manufacturing companies are reducing the degree of digitalization of the innovation process in order to minimize cyber risks.
Source: ZEW Business Survey in the Information Economy, 3rd quarter 2019. Calculations in ZEW (2020).

Number of transnational patents in the field of cybersecurity (top 10 countries and EU) 2000–2017

Fig. B 2-5

Download data



Source: own diagram based on calculations by the Max Planck Institute for Innovation and Competition.

minimize cyber risks, 19.2 percent of manufacturing companies with 5 to 19 employees are reducing the degree of digitalization of their innovation process. This applies to only 4.7 percent of manufacturing companies with 20 to 99 employees and to 3.6 percent of companies with a staff of over 100. Reducing the degree of digitalization in response to cyber threats appears particularly critical if there is a risk of losing productivity potential.

Patent activities in cybersecurity

In view of increasing and ever-changing cyber risks,[175] there is a great need to counter these risks with innovative cybersecurity solutions. Innovations in cybersecurity make it possible to both increase the level of protection and expand potential for value creation.[176] Patent applications can provide an indication of innovation activities.[177] For the following analysis, the Commission of Experts refers to international patenting activities that can be illustrated by transnational patent applications. The assignment of the patents to countries is based on the nationality of the first applicant. Figure B 2-5 shows the distribution of transnational patent families in the field of cybersecurity for the years 2000 to 2017 for the ten countries with the most patents plus the EU.[178] With 6.2 percent of patents, German inventors are a long way behind inventors from the USA (33.5 percent), Japan (13.7 percent) and China (11.6 percent). Inventors from EU countries together account for 21.5 percent. The USA and China became increasingly important over the period under consideration and show an above-average increase in patent applications, especially at the end of the period considered.[179]

A comparison between a country's patent activities in the field of cybersecurity with the country's patent activities as a whole reveals that Germany, unlike the USA and Israel, is not specialized in the field of cybersecurity.[180] This specialization by the USA and Israel is also reflected in evaluations made by the American industry analyst Cybersecurity Ventures, according to which 112 of the world's 150 most innovative cybersecurity companies come from the USA, 18 from Israel and only one from Germany.[181]

Challenges at the company level B 2-2

A number of obstacles can contribute to companies failing to achieve the level of protection they need against cyber risks. These include, in particular, the problem of recruiting cybersecurity experts who can improve protection and detect and ward off attacks. In addition there is lack of information on current threat situations, on the extent of damage, and on the quality of IT security products.

Need for experts and competencies

The lack of qualified IT security experts poses a threat to IT security in many companies.[182]

The European Commission has carried out a study in the EU Member States to determine how long it takes to fill vacancies requiring digital skills.[183] This analysis shows that a relatively high proportion of job vacancies in the field of cybersecurity are still unfilled after 90 days. In fields like machine learning and the Internet of Things, a much larger proportion of these positions are filled after 90 days than in cybersecurity.[184]

The high demand for cybersecurity experts is matched by only a few courses of study for cybersecurity experts in Germany.[185] No student statistics are available for the relatively young subject of cybersecurity. Up to now, cybersecurity topics have mostly been taught in computer science courses. The number of students studying computer science rose from 69,559 in the 2010/2011 academic year to 115,005 in 2017/2018, i.e. by almost two thirds.

Because cyberspace touches on many areas of life, it is important to understand cybersecurity not only as a purely technical discipline. For example, there are interfaces with the social sciences, economics and law. When planning study programmes, these should be taken into account accordingly.

Not only academically trained specialists are needed to improve the level of cybersecurity across the board; cybersecurity should also be increasingly integrated into vocational education and training. This could take account of the fact that the level of cybersecurity is not only determined by technical innovations but also by the way people handle hardware and software. There is currently no specific training programme for IT security experts. Training programmes are currently being modernized for IT professions such as computer science expert, IT management assistant, electronics technician for IT systems, and management assistant for IT systems.[186] Since August 2018, IT security has been increasingly included into content of apprenticeship training.

A total of 16,869 new training contracts were concluded in these four IT occupations in 2017. Furthermore, a new recognized occupational profile, 'digitalization of labour, data privacy and information security', has been added to apprenticeship programmes in industrial metal and electrical occupations and for mechatronics technicians teaching content on information security in an integrative way.

In order to develop cybersecurity skills and adapt them to changing requirements, it is in companies' own interests to provide advanced training for their cybersecurity experts and to make use of existing personnel resources. In addition to classic further training courses, innovative approaches can also make a contribution. For example, there are courses offered using methods such as gamification that train staff to ward off attacks (cf. box B 2-6).

In addition to cybersecurity experts, all other employees also have an impact on the level of cybersecurity in a company. For example, emails, which are an important part of everyday working life for most company employees, are often used as a gateway for cyberattacks.[187] In a survey of companies conducted by KPMG,[188] 90 percent of companies counted carelessness and 83 percent of companies counted insufficiently trained personnel among the factors that favour e-crime.[189] It is therefore important to raise awareness and offer further training to the entire workforce on cybersecurity. Many companies already have appropriate measures in place. However, surveys show that smaller companies are less active here.[190]

Reducing the lack of information

A lack of information makes it more difficult for companies to deal with cyber threats.[191] For one thing, companies cannot reliably assess the risk of cyberattacks and any resulting damage. For another, as buyers they often have difficulty in assessing the quality of cybersecurity products and services due to the high and increasing complexity of IT systems and rapidly changing security requirements.

Various measures can be taken to reduce the lack of information on the risks of cyberattacks and the resulting damage. Operators of critical infrastructures, providers of online services and telemedia providers are legally obliged to report cyberattacks to the BSI. For its part, the BSI issues warnings and information via the Federal Government's Computer Emergency Response Team (CERT-Bund).[192] In addition, there are initiatives in which companies exchange information on cyberattacks with each other or with government agencies.[193] However, small and medium-sized enterprises (SMEs) in particular

Box B 2-6

Example: Further training through gamification

The skills required to ward off cyberattacks must be regularly trained and updated. Providers of so-called cyber ranges offer such training. However, cyber ranges are often located on providers' premises, so cybersecurity professionals may be absent from the company for some time for training, thus increasing the training costs.

The Israeli company Cympire has developed a software-based cyberattack defence training environment that can replicate the customers' IT infrastructure. This means that training courses can be held regardless of location, and the time required can be reduced. In addition, the services offered by Cympire include innovative elements such as gamification, which are suitable for increasing experts' motivation to train.

often do not have the necessary resources to become involved in such initiatives.

Further measures for reducing information asymmetries in the market for cybersecurity products and services include certification, quality seals and minimum standards. Liability rules that make manufacturers responsible for security breaches in the event of damage are another possible way of dealing with information asymmetries. This creates incentives to already pay more attention to security during product development (security-by-design) in order to avoid compensation payments or expensive insurance policies.[194]

Germany has a national certification body for IT security, the BSI, where companies can apply for certification as an IT security service provider or for security or staff certification for certain products or services.[195] European-level implementation of both certifications and minimum standards of IT security started only recently and represents a very complex challenge. The EU Cybersecurity Act,[196] which came into force in June 2019, forms the foundation for certification. As a legal framework for market and product surveillance, the New Legislative Framework[197] serves as a basis for minimum standards of cybersecurity in products.

Insurance against cyber risks

Apart from investing in cybersecurity, companies can take out cyber-insurance policies to limit their costs from cyberattacks. Cyber insurances are often a combination of liability, business-interruption and data insurance covering both a company's own and third-party losses.[198] The benefits of cyber insurance can include:[199] compensation for business interruptions, reimbursement of data-recovery costs, assumption of third-party losses, payment of IT forensics, offer of legal advice for data breaches, payment for crisis communication, and call-centre costs.

The first cybersecurity policies in Germany came onto the market in 2011.[200] Accordingly, this is a relatively young insurance market. According to a survey conducted by Bitkom, 14 percent of industrial companies have taken out cyber insurance.[201] This share varies between small, medium-sized and large companies. Ten percent of companies with 10 to 99 employees have cyber-insurance. The share for companies with 100 to 499 employees is 23 percent and for companies with more than 500 employees 32 percent.

Reasons given for not taking out cyber insurance include the assessment of a low risk of exposure to cyberattacks, an unfavourable cost-benefit ratio, or excessive costs of risk assessment.[202]

Cybersecurity and the role of the state B 2-3

The state has various roles to play in maintaining cybersecurity. By funding R&D in cybersecurity, it helps create the necessary expertise for protection against cyberattacks. At the same time, it supports the role of cybersecurity as a driver of innovation, which can lead to new products and services. The state also provides reliable information on the threat situation and possible protective measures. Based on this information, companies can better manage their cybersecurity activities and protect their innovation activities. In addition, it is the responsibility of the state to ensure security in cyberspace through legal and regulatory measures and law enforcement.[203]

R&I funding for cybersecurity

With its research framework programme 'Self-Determined and Secure in the Digital World 2015–2020', the Federal Ministry of Education and

Research (BMBF) is funding research in IT security with about €180 million.[204] The main priorities of this research framework programme are high-tech technologies for IT security, secure and trustworthy ICT systems, application areas of IT security, and privacy and data protection. As part of the research framework programme, the three competence centres CISPA[205] (Saarbrücken), KASTEL[206] (Karlsruhe) and CRISP[207] (Darmstadt) have been funded by the BMBF since 2011. In December 2019, the CRISP competence centre led to the National Research Centre for Applied Cybersecurity ATHENE, which combines the work of more than 500 researchers from the Fraunhofer Institutes SIT and IGD, Darmstadt Technical University (TU) and Darmstadt University of Applied Sciences.[208]

The BMBF has also been funding the start-up incubator StartUpSecure with €2 million a year from 2017 to 2020. Partners are CISPA, CRISP, KASTEL and the Horst Görtz Institute for IT Security at the Ruhr University Bochum.[209] According to the BMBF, StartUpSecure has initiated ten start-ups so far.

The Central Office for Information Technology in the Security Sector (Zentrale Stelle für Informationstechnik im Sicherheitsbereich, ZITiS) conducts research and development in the fields of digital forensics, telecommunications surveillance, and crypto- and Big-Data analysis. The budget of ZITiS in 2019 was approximately €36 million. With the establishment of the Agency for Innovation in Cybersecurity (Agentur für Innovation in der Cybersicherheit, Cyber Agency), the Federal Government is also investing up to €402.5 million in new cybersecurity technologies up to 2023.[210] The Cyber Agency is to be founded as a limited liability company and will begin business operations this year.[211] The Cyber Agency aims to initiate and promote R&I projects in the field of cybersecurity and to accelerate procurement procedures.[212, 213] However, the Cyber Agency will be more closely linked to politics than the civil SprinD (cf. chapter A 1). This stronger connection with politics includes a transparency obligation vis-à-vis the German Bundestag, whose budget committee also decides on new lines of business or spin-offs, for example. Furthermore, in the selection of its projects the Cyber Agency is guided essentially by the needs of the two supervising ministries, the Federal Ministry of Defence (BMVg) and the Federal Ministry of the Interior, Building and Community (BMI).

Education and raising awareness

Since 2011, with the initiative 'IT Security in Commerce', the Federal Ministry of Economics and Energy (BMWi) has supported measures to sustainably improve awareness of IT security, especially among SMEs.[214] Among other things, the initiative offers IT security checks[215] and an IT security navigator[216] to help companies improve their data protection and provide an overview of the assistance on offer. Campaigns such as 'SME aware – Awareness in SMEs'[217] or the poster campaign 'IT security is NOT a game'[218] aim to raise companies' awareness of cybersecurity. Other programmes such as the BMBF's 'SME innovative: ICT'[219], the BMWi's 'go-digital' or 'SME 4.0 Competence Centres', and the KfW's 'ERP Digitalization and Innovation Loan' also contain elements aimed at promoting IT security.

The BSI performs a central task in the field of cybersecurity (cf. box B 2-1); its primary tasks include providing information and advice on all important IT security issues and supporting the implementation of appropriate measures.[220] As well as citizens[221] and companies,[222] the BSI also provides the federal and Länder administrations[223] with information and advice. It uses different formats such as annual situation reports, reports from the CERT-Bund[224] or Citizen CERT, and cooperation platforms such as the Alliance for Cybersecurity.[225]

In addition, the 'Germany Safe on the Net' (Deutschland sicher im Netz) initiative, an association under the auspices of the Federal Ministry of the Interior, provides a wide range of services for consumers and small businesses on how best to deal safely and confidently with the digital world.[226]

Measures for secure digital infrastructures

It is the task of the Federal Government – and its European partners – to ensure the security of digital infrastructures. The development of the new 5G standard in the mobile network has made policy makers and the public much more aware of digital infrastructure security. A recommendation by the European Commission aims to develop a toolbox defining both technical and non-technical criteria for assessing cyber risks for 5G networks and includes measures for making 5G networks secure.[227] Non-technical criteria for cyber risks can, for example, include the trustworthiness of producers or sources

of supply and take into account their regulatory environment. Promoting diversity among producers and suppliers in the European internal market can help make networks more resilient.[228] Furthermore, multilateral projects such as the GAIA-X data cloud (cf. chapter A 1) aim to encourage the creation of secure digital infrastructures at the national and EU level.

B 2-4 Recommendations

The Federal Government recognized the importance of cybersecurity at an early stage and, among other things, launched R&D programmes and information measures to boost cybersecurity. In addition, the BSI was developed into the central institution for ensuring cybersecurity. However, the threat landscape for businesses is subject to constant change, so that implemented programmes for promoting cybersecurity need to be reviewed and, if necessary, adapted. From an innovation-policy perspective, it is particularly critical that companies delay innovation projects – or do not even begin projects in the first place – due to the danger of cyberattacks. Against this background, the Commission of Experts recommends the following:

Meet the demand for skilled workers and skills

- Teaching cybersecurity skills in vocational training and higher education should be further promoted to meet the growing demand for cybersecurity experts. Such moves should cover not only technical dimensions, but also deal with legal issues (cyber law) and ethical aspects (cyber ethics).

Ensure the security of digital infrastructures

- The approval of digital infrastructure components should be based on criteria that apply throughout the European single market. These criteria should take into account technical and non-technical aspects and apply equally to EU and non-EU suppliers. Corresponding initiatives by the European Commission, e.g. on the roll-out of 5G networks, should be supported.
- The Federal Government should push ahead with multilateral initiatives such as the GAIA-X data cloud in order to provide impetus for the establishment of secure digital infrastructures at the national and EU level.

Launch Cyber Agency quickly

- The Cyber Agency should begin operations quickly and practise demand-driven procurement to promote innovative projects that help protect Germany's technological sovereignty in cybersecurity. It is important here to constantly and openly follow new technological developments to be able to react flexibly to changing needs. An evaluation of the Cyber Agency should examine what stimuli it generates for R&I activities in cybersecurity.

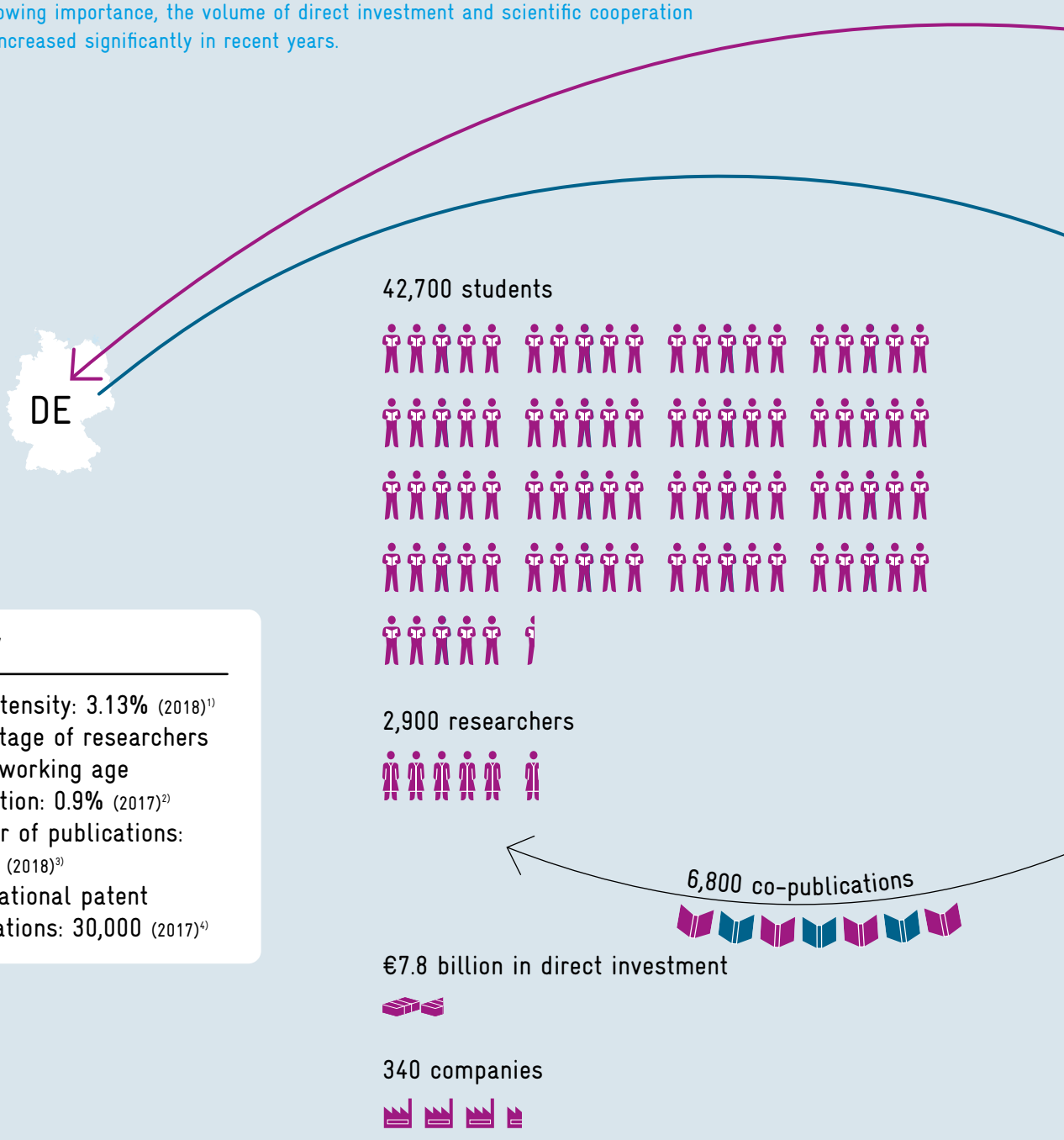
Improve information on cyber threats

- It is particularly important to provide easily accessible information and advisory services for SMEs. The effectiveness of implemented programmes to promote cybersecurity in SMEs should be reviewed and adapted to the constantly changing threat situation.
- In order to improve the information available on the quality of cybersecurity products and services, initiatives should be supported which are aimed at developing minimum standards and certification systems, particularly at the European level.
- There is a need to consider whether the existing reporting obligations need to be extended in order to improve the information available on cyber risks and to deal more effectively with cyber threats.

B 3 Exchange of knowledge and technology between Germany and China

Download data

The international exchange of knowledge and technology is a key driver of innovation and value creation. Germany, therefore, has a real interest in good cooperative relations in science and business with the emerging location for innovation, China. With China's rapidly growing importance, the volume of direct investment and scientific cooperation has also increased significantly in recent years.



Germany

- R&D intensity: 3.13% (2018)[1]
- Percentage of researchers in the working age population: 0.9% (2017)[2]
- Number of publications: 74,000 (2018)[3]
- Transnational patent applications: 30,000 (2017)[4]

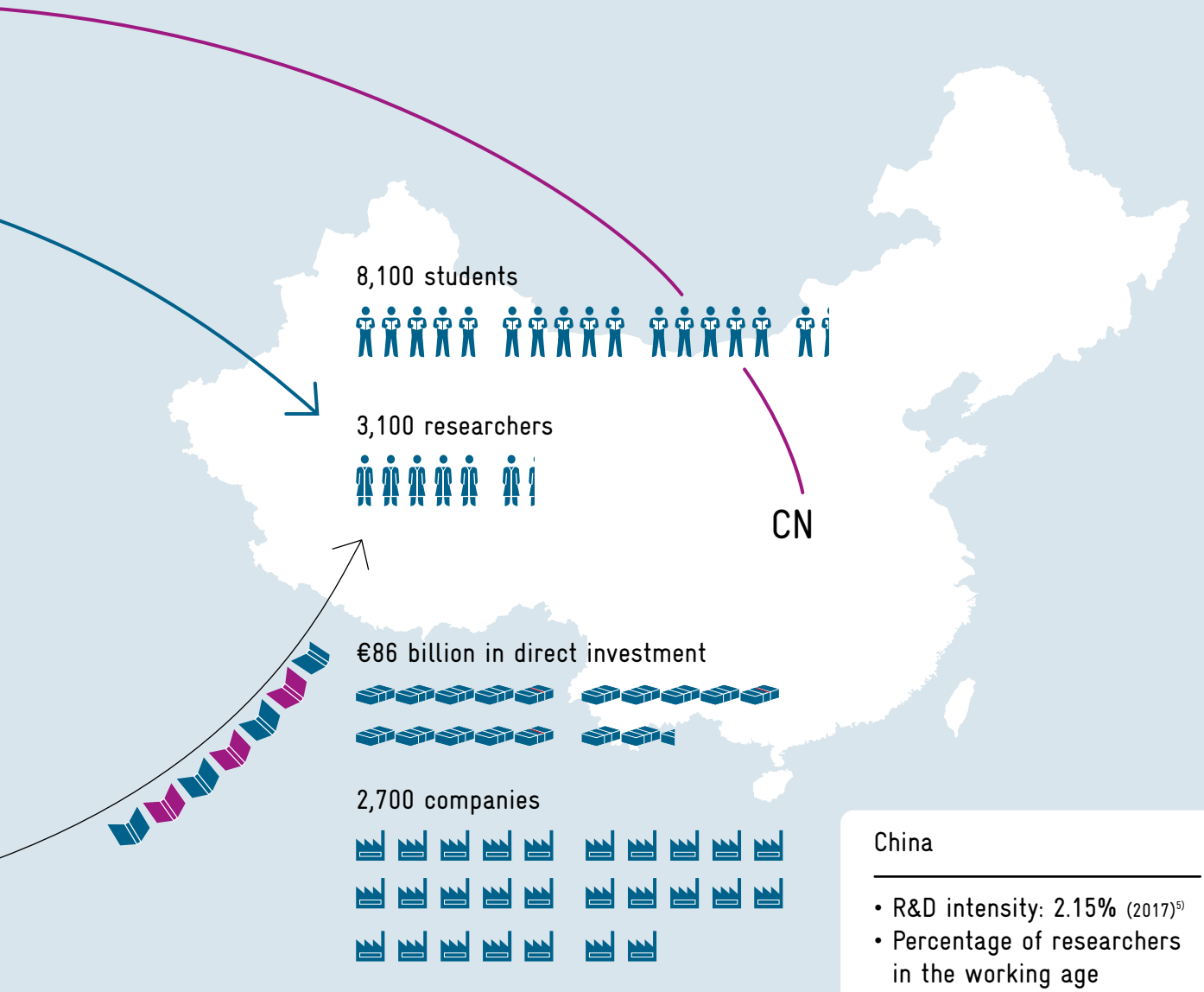
corresponds to 500 students[9]
- Chinese students in Germany (2018/19 winter semester)
- German students in China (2018)

corresponds to 500 researchers[10]
- Publishing scientists affiliated to an institution in the other country (2006 to 2016)

corresponds to 500 co-publications[11]
- Co-publications by Chinese and German scientists (2017)

corresponds to five billion euros[12] in foreign direct investment (FDI)
- Chinese FDI in Germany (2017)
- German FDI in China (2017

corresponds to 100 companies[13]
- Companies in China taken over or launched by a German investor or German shareholders (2017)
- Companies in Germany taken over or launched by a Chinese investor or Chinese shareholders (2017)



China

- R&D intensity: 2.15% (2017)[5]
- Percentage of researchers in the working age population: 0.2% (2017)[6]
- Number of publications: 355,000 (2018)[7]
- Transnational patent applications: 52,000 (2017)[8]

See chapter D 7 for a list of sources of the infographics.

B 3 Exchange of knowledge and technology between Germany and China

The People's Republic of China (hereinafter referred to as China) has developed into one of the world's leading industrial nations and one of Germany's most important trading partners.[229] The Chinese government is working systematically to strengthen the country's regional and global power position. To this end, one of its strategic goals in the coming years is to gain technological leadership in key future industries and to become the world's leading location for innovation.[230]

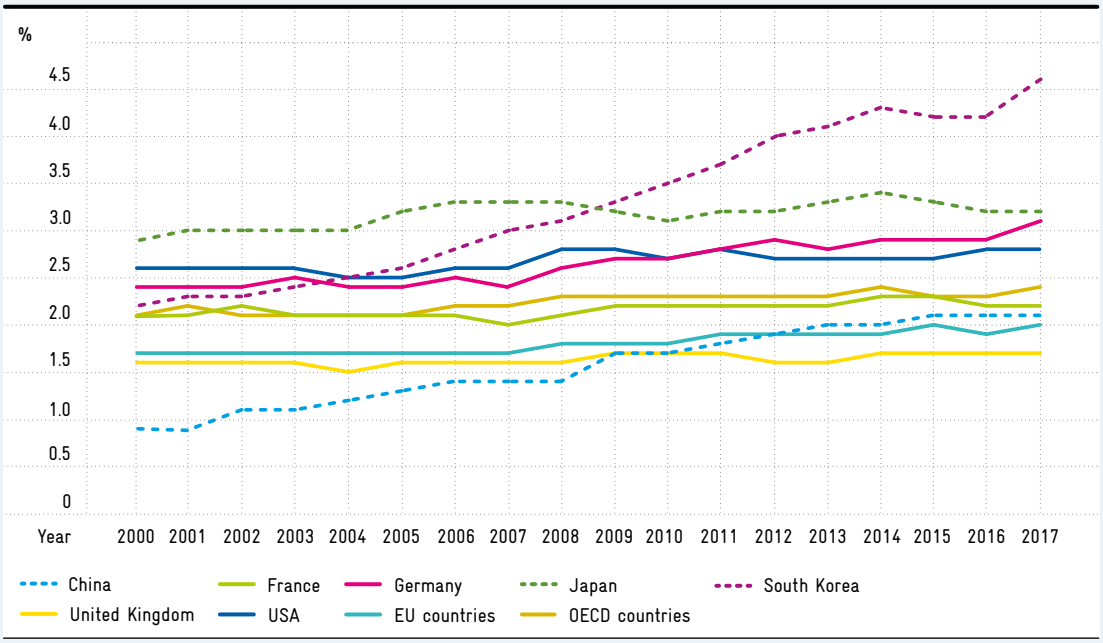
China's research and innovation (R&I) policy is characterized by strong state control. The Chinese Communist Party has a pivotal planning and decision-making role in all policy areas. It also determines the strategy and instruments of China's R&I policy, which is characterized by long-term planning with highly ambitious targets.[231] Examples of this are the Made in China 2025 strategy, which focuses on the development of high-tech sectors, and the 'Belt and Road Initiative', which aims at expanding intercontinental trade and infrastructure networks up to 2049.[232]

The international exchange of knowledge and technology is a key driver of innovation and value creation. Germany therefore has strong interest in good cooperative relations in science and business with China as an emerging location of innovation. However, from the perspective of national and European decision-makers the increasing influence on science and business imposed by the Chinese

Fig. B 3-1

Download data

R&D expenditure as a percentage of gross domestic product 2000–2017

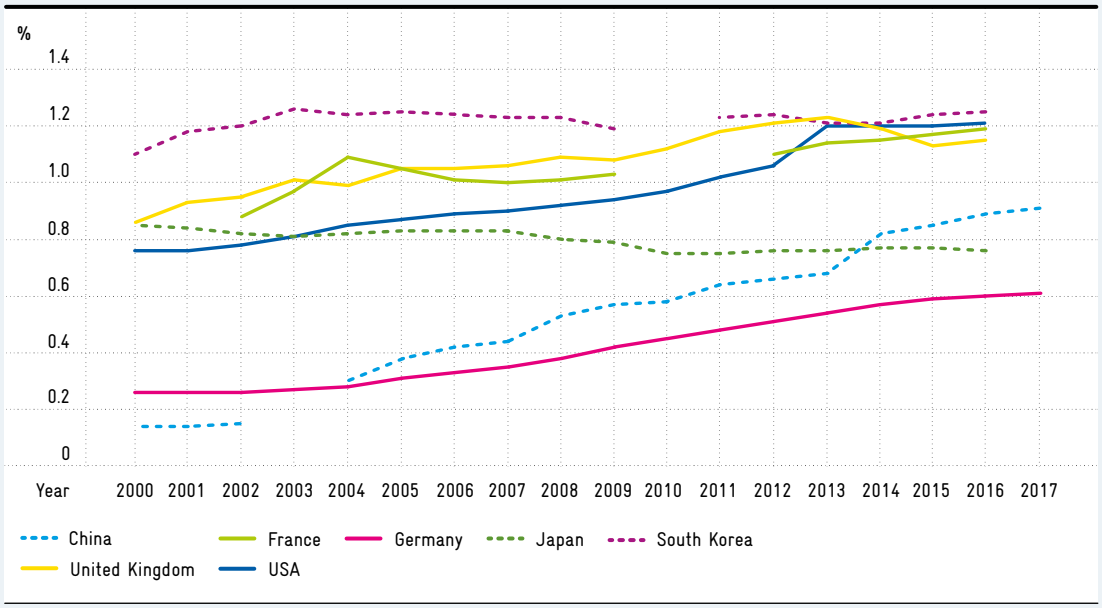


Source: Gehrke et al. (2020b).

Fig. B 3-2

Download data

Tertiary graduates per year as a percentage of the total population 2000–2017



Source: Conlé et al. (2018). Data for APRA monitoring using data from Destatis and the World Bank.

government is putting a strain on cooperation.[233] There is concern that a one-way outflow of scientific, innovation- or security-related know-how[234] and unequal competitive conditions could weaken Germany's scientific and economic performance.[235]

Against this background, the Commission of Experts examines different dimensions of knowledge and technology exchange between Germany and China. It outlines the framework conditions that form the basis for relations between the two countries in science and business.

B 3-1 China's research and innovation system

China is a rapidly emerging location for innovation, as selected input and output indicators of the research and innovation system (R&I system) show.[236]

An important input indicator of the performance of an R&I system is the expenditure on research and development (R&D). China's R&D expenditure has multiplied from around US$33 billion in 2000 to about US$496 billion in 2017.[237] China is thus only behind the US in terms of absolute R&D expenditure[238] and nowadays invests a higher percentage of its gross domestic product in R&D than the average of the EU countries (cf. figure B 3-1). China has become the world's biggest exporter in the field of research-intensive goods.[239]

A distinctive feature of the Chinese R&I system is the low percentage of R&D spending on basic research, just 5.5 percent in 2017. By contrast, 10.5 percent was spent on applied research, and 84 percent of R&D spending on product development and commercialization.[240]

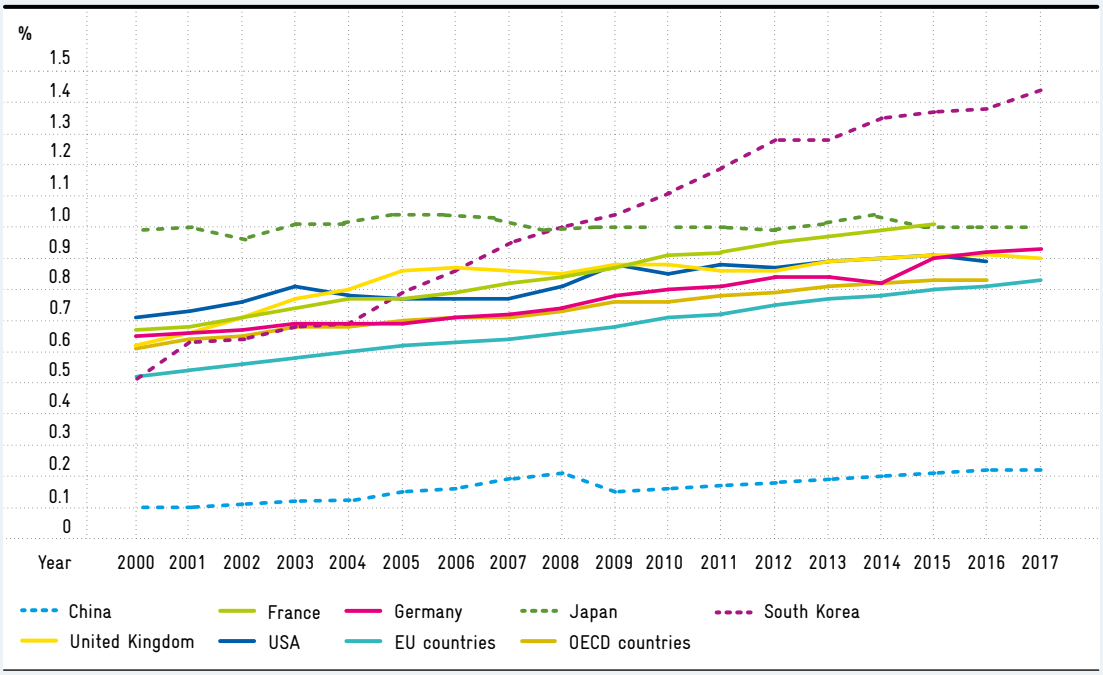
The bulk of Chinese government research funding is concentrated on a (relative to population size) small number of selected institutions that engage in cutting-edge research. These include the institutes of the Chinese Academy of Sciences (CAS) and several leading universities. In international rankings, a handful of Chinese universities achieve top 100 positions.[241] Since 2015, the Chinese government has established several funding programs in which selected tertiary education institutions receive additional financial support with the aim of developing them into world-leading universities.[242]

Another important indicator of an R&I system's performance is the number of university graduates as a percentage of the total population. This figure has been growing faster in China than in important OECD countries since 1997 (cf. figure B 3-2). In 2017, over seven million tertiary students completed

Fig. B 3-3

Download data

Number of scientists per 100 employees 2000–2017

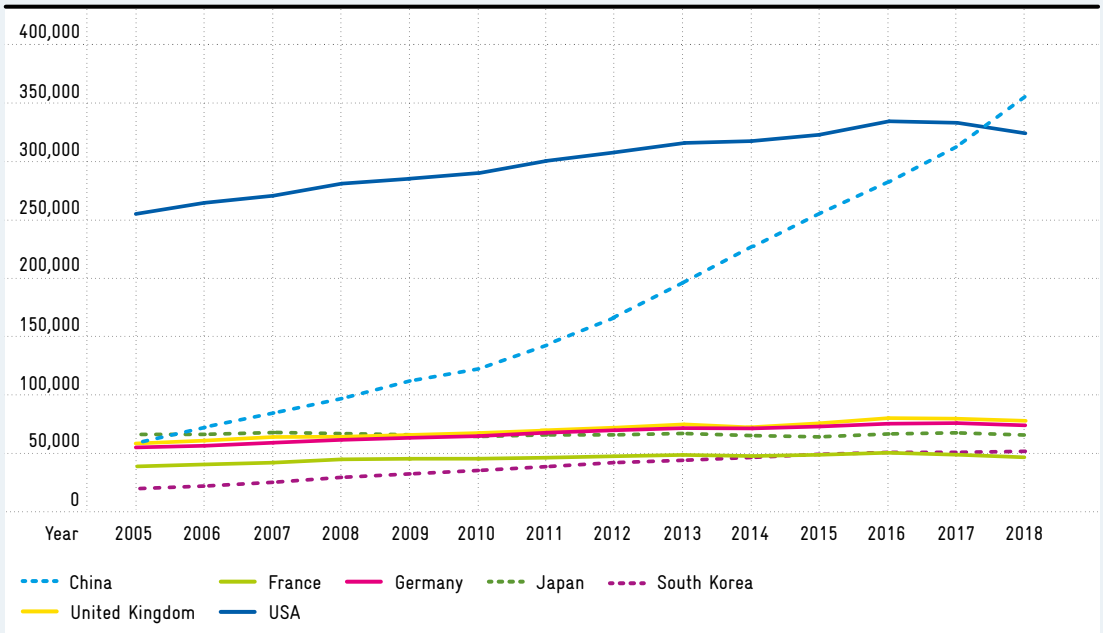


Source: https://data.oecd.org/rd/researchers.htm (last accessed on 17 January 2020).

Fig. B 3-4

Download data

Number of scientific publications, fractional counting 2005–2018[1)2)]



[1)] Publication development that can be assigned to individual countries by the authors' addresses.
[2)] Fractional counting is used in cases where several co-authors from different countries contribute to a publication. If there are four authors from four countries, each country receives 0.25 credits for a publication.
Source: Web of Science. Calculations by DZHW.

their studies – more than 40 percent of them in the fields of science, technology, engineering and mathematics (STEM).[243] However, the rapid increase in the number of graduates is in parts not well-aligned with the development of labour demand. This shows in many university graduates having difficulties in finding jobs that match their qualifications.[244]

Besides the share of university graduates in the total population, another indicator of R&I system performance is the number of scientists as a percentage of the working age population. At 0.2 percent, this proportion in China is still well below the OECD average, despite a rising trend (cf. figure B 3-3). The share of scientists in the working age population is about 1 percent in Germany, and as high as 1.4 percent in South Korea, the front runner in this field.

A relevant output indicator of the performance of an R&I system is the number of scientific publications. In 2018, 355,000 scientific publications were attributed to scientists affiliated with China – a six fold increase over 2005 (cf. figure B 3-4).[245] For the first time, China had thus overtaken the US as the country with the most scientific publications. This rise was associated with an increase in the average quality of publications – as measured by the excellence rate.[246]

The excellence rate of Chinese publications rose from 6.7 to 9.7 percent between 2005 and 2016. Most recently it was above the excellence rate of Japanese (5.8) and South Korean publications (6.3), but still below that of German (10.9 percent), US-American (13.2) and British publications (13.5 percent).[247]

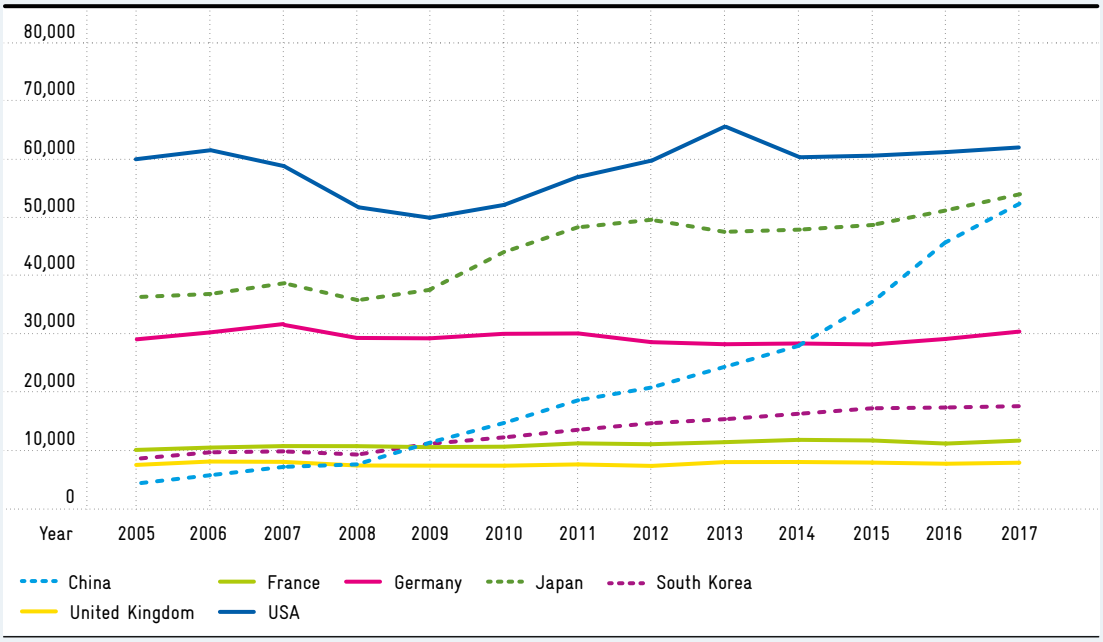
The number of transnational patent applications from China has also increased massively since 2005 (cf. figure B 3-5). With around 52,000 transnational patent applications in 2017, China was ahead of Germany (with 30,000), but still behind the US (64,000) and Japan (54,000).[248] However, only 69 transnational patents per million workers were registered in China in 2017. The number was significantly higher in Germany (730), Japan (826) and the US (404).[249] Chinese transnational patent applications concentrate in particular on information and telecommunications technologies.[250]

There are indications that the average quality of Chinese transnational patent applications is still rather low. That they are cited comparatively seldom abroad supports this impression.[251] In terms of content, these patents often only reflect the current state of the art or describe simple technical solutions.[252]

Transnational patent applications 2005–2017

Fig. B 3-5

Download data



Source: EPO (PATSTAT). Calculations by Fraunhofer ISI in Neuhäusler et al. (2020)

Box B 3-6

Explanation of key terms

Foreign Direct Investment (FDI): Cross-border capital investment to exercise control over – or significantly influence – the management of the target of the direct investment. Direct investments are defined as cross-border holdings of the capital and reserves of companies, provided that at least ten percent of the shares or voting rights are directly attributable – or more than 50 percent of the shares or voting rights are directly and indirectly attributable – to the investor.[253] FDI essentially comprises four types of transactions: mergers and acquisitions (M&A), start-ups (greenfield investments), capital expansion (additional new investments) or financial restructuring.[254]

Net direct investment: Inflow of equity capital, reinvested earnings, purchases of land and property, and newly issued direct investment loans minus liquidation of previously paid-in equity capital, profit withdrawals, and repayment of direct investment loans.[255]

Majority interest: Investment in a company in which an investor holds more than 50 percent of the capital shares.[256]

Acquisition or takeover: The purchase of a company by another company. The acquiring company receives all the assets and liabilities of the target company.[257]

Joint venture: A contractual arrangement between two or more parties to execute a transaction in which the parties share the profits and losses of the transaction and jointly pay for the provision of capital, working capital and costs. A joint venture does not necessarily lead to the creation of a new legal entity.[258]

Knowledge and technology exchange through direct investment B 3–2

Chinese direct investment in Germany

Chinese direct investment in Germany has increased sharply in the last ten years.[259] The impression in Europe and the US is that these FDI activities serve the strategic goal of Chinese policy-makers to establish a dominant position in key technology areas. This is associated with the concern that the countries affected will lose considerably in terms of technological sovereignty and international competitiveness in the long term (cf. p. 58).[260]

Compared to investors from other countries, Chinese investors worldwide more often acquire companies that are larger and hold more patents. They also often take over less profitable and more indebted companies.[261] This could mean that Chinese investors are pursuing objectives other than return on their investments with their takeovers. Other possible explanations are that they have longer time horizons for their investment decisions or take advantage of more favourable financing possibilities due to state aid, enabling them to pursue riskier investment strategies.[262]

According to a recent empirical study, the areas of Chinese acquisitions abroad differ significantly depending on whether the investors are private or public. State-owned companies as investors engage primarily in industries that are key to the politically defined strategies, i.e. Made in China 2025 and the Belt and Road Initiative. This orientation of investment behaviour cannot be observed among private investors.[263]

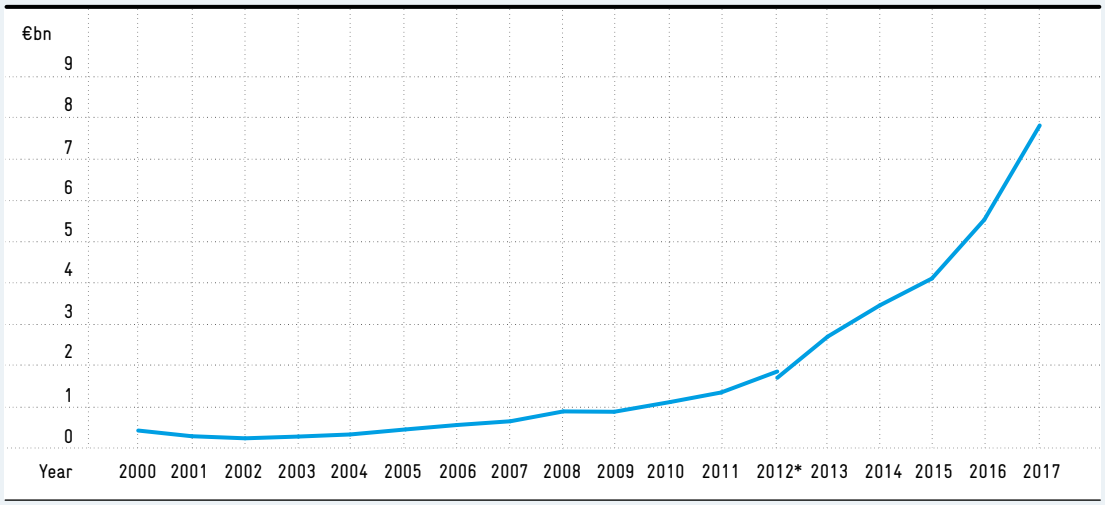
The direct investment statistics of the Deutsche Bundesbank documented a total of 342 companies with Chinese shareholders in Germany in 2017. The level of Chinese direct investment has been growing faster and faster since the mid-2000s (cf. figure B 3-7). In 2010, it exceeded the one billion euro mark for the first time and reached a value of €7.8 billion in 2017.[264] However, this still lay well behind total direct investment in Germany from other EU countries (€320 billion) and the US (€98 billion).[265]

A study by the ZEW – Leibniz Centre for European Economic Research (ZEW) has examined a selection of 261 German companies that were taken over by Chinese investors, or in which Chinese investors had shareholdings, between 2002 and early 2019.[266]

Fig. B 3-7

Download data

Total Chinese direct investment in Germany 2000–2017 in €bn



*since 2012: calculated according to the OECD Benchmark Definition, 4th edition.
Source: own diagram based on Dürr et al. (2020: 9) based on data from the Deutsche Bundesbank.

187 of these companies were taken over completely by Chinese investors or had a Chinese majority shareholding.

Of the 261 companies in the sample, 48 percent had less than 100 employees at the time of the takeover, 38 percent were medium-sized (100 to 1,000 employees), and the rest had more than 1,000 employees.[267] One in ten companies were involved in insolvency proceedings.[268] Just over three-quarters of the Chinese takeovers and shareholdings examined are concentrated in the manufacturing sector. 28 percent of the companies examined here belong to the mechanical engineering sector, 16 percent to the automotive sector, and 10 percent to the electronics sector (cf. figure B 3-8).[269]

According to a study by the Bertelsmann Stiftung, companies that can be assigned to one of the ten key sectors of the Made in China 2025 strategy account for almost two-thirds of Chinese investments and takeovers in Germany.[270]

72 percent of the companies with Chinese direct investment covered in the ZEW study are engaged in R&D. This percentage of R&D-active companies is thus significantly higher than among the German economy as a whole. However, the R&D intensity[271] of these companies is below the respective sectoral average of the German economy (cf. figure B 3-9). Mechanical engineering companies are an exception. In this sector, the R&D intensity of companies with Chinese investors (5.2 percent) is significantly higher than in German mechanical engineering as a whole (3.6 percent).[272]

More than half of the companies examined had applied for patents in the ten years prior to the investors' involvement.[273] In total (and consolidated) they applied for approximately 5,700 patents[274], corresponding to an average of around 43 patents per patent-active company.[275] However, this high figure is due to the fact that a small number of companies are responsible for most of the patent applications observed. The median of patent applications by patent-active companies was only two per year before the Chinese acquisition or shareholding.

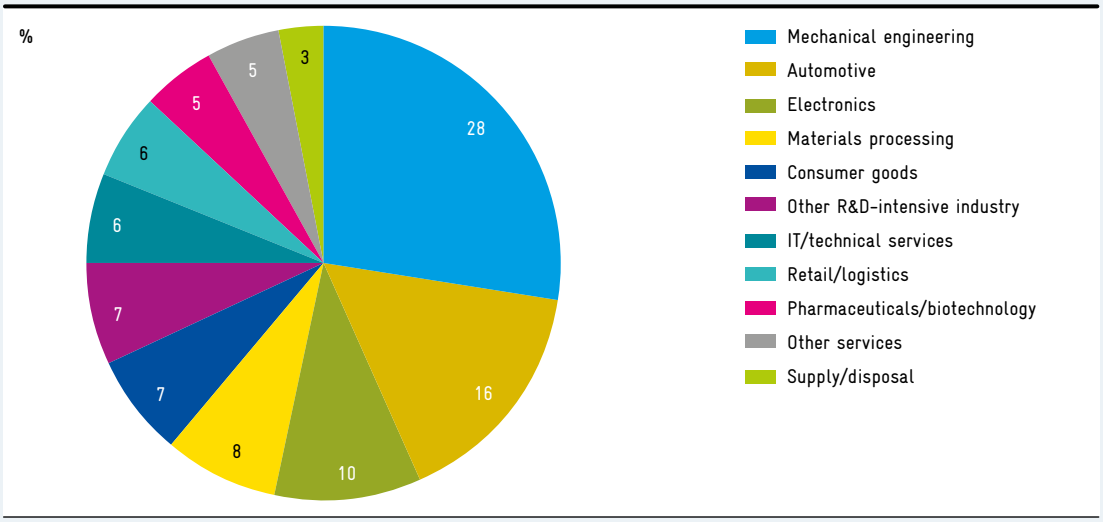
The ZEW study also analyses whether the 187 companies that were taken over by Chinese investors either completely or by more than 50 percent developed differently after the takeover than companies taken over by investors from the rest of the EU, Japan or the US. It does not find evidence of significant differences in terms of the development of the number of employees, turnover or the number of patent applications.[276]

Furthermore, a descriptive data analysis by the Wissenschaftsstatistik GmbH of the Stifterverband, commissioned by the Commission of Experts, of the R&D statistics for the period 2007 to 2017 suggests

Fig. B 3-8

Download data

Percentage of German companies taken over by Chinese investors or with Chinese shareholdings by sector

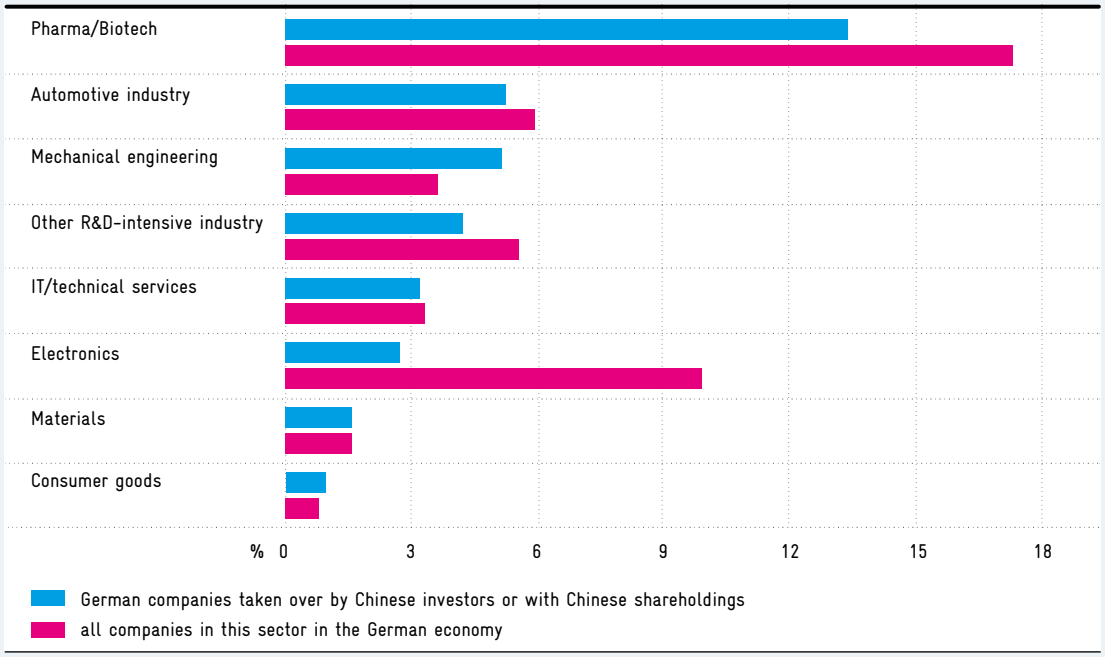


Source: own diagram following Dürr et al. (2020: 22) based on data from the Mannheim Innovation Panel.

Fig. B 3-9

Download data

R&D intensity of companies taken over by Chinese investors or with Chinese shareholdings, and of all companies in the German economy by sector, as percentages



Only companies that were still part of a Chinese corporate group and economically active at the beginning of 2019 are included.
R&D intensity: total R&D expenditure as a percentage of turnover, in the case of internationally active companies only in relation to Germany as a business location; for German companies taken over by Chinese investors or with Chinese shareholdings in 2018 or the most recent available year, for German industry as a whole in 2017.
Source: own diagram following Dürr et al. (2020: 26) based on data from the Mannheim Innovation Panel.

that companies taken over by Chinese investors or with Chinese shareholdings do not reduce their R&D expenditure or R&D personnel.[277]

Current measures to control Chinese direct investment

Chinese direct investment, like FDI from other non-EU countries, is subject to several forms of government regulation at the national and European level. Current efforts are aimed at strengthening the control mechanisms on FDI.[278]

In Germany, the 'Foreign Trade and Payments Ordinance' was amended in 2017 and 2018. With the amendments, the Federal Government aimed at improved protection for German companies from takeovers whenever important know-how might be lost as a result.[279] Another objective was to strengthen national security.[280] The amended Foreign Trade and Payments Ordinance stipulates that the acquisition of company shares by non-EU investors should be reviewed if the intention is to acquire at least 25 percent of the voting rights in a company located in Germany. The review criterion is whether the acquisition endangers public order, security or Germany's essential security interests. Furthermore, the amendments lowered the threshold for the examination of shareholdings in critical infrastructure operators, in security and defence-related companies, and in media companies from 25 to 10 percent of the voting rights.[281]

The Federal Ministry of Economics and Energy (Bundesministerium für Wirtschaft und Energie, BMWi) presented further proposals for controlling FDI in November 2019 with its Industrial Strategy 2030. The aim of investment control is to maintain Germany's technological sovereignty. FDI is to be reviewed to determine whether it affects security-related or so-called sensitive technologies. To enable rapid action, the BMWi proposes the establishment of a standing committee called 'National Recourse Option' at the state secretary level.[282]

In April 2019, the Regulation of the European Parliament and of the Council establishing a framework for screening foreign direct investment into the European Union came into effect. It aims to improve information exchange and cooperation between the member states with respect to screening foreign direct investment from non-EU countries. Furthermore, the European Commission can issue statements if an investment poses a threat to security or public order in more than one member state.[283] The EU member states are not obliged to comply with these statements but must give specific reasons if they do not.[284] National screening procedures, like those that already exist in Germany and some other member states, remain unaffected by this regulation.[285]

German direct investment in China

The volume of German direct investment in China has increased significantly since the early 2000s. In 2017, it reached a value of €86 billion – an increase of more than €75 billion (cf. figure B 3-10). Hence, German FDI in China at that time was about eleven times higher than Chinese FDI in Germany.[286]

The development of German FDI in China can be divided into several phases (cf. figure B 3-11). From 2000 to 2008, there was comparatively little activity. The annual volume of net direct investment was around €2 billion. After that, there was a strong expansion. In a peak phase that lasted from 2010 to 2016, German FDI in China almost continuously exceeded €7 billion per year. The peak was reached in 2014 with a volume of €10 billion. Most recently, the volume of annual net direct investment has declined sharply, amounting to only €1.6 billion in 2018.

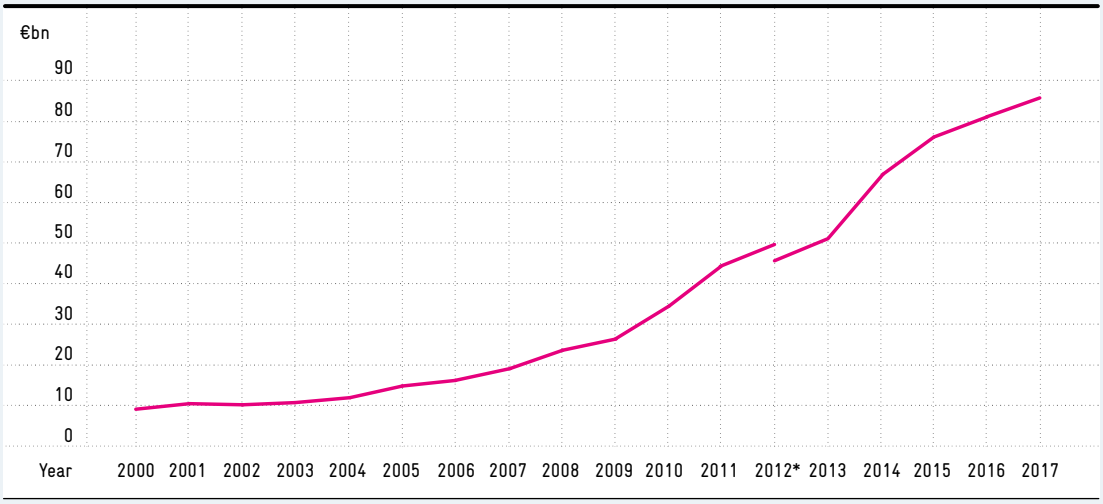
According to direct investment statistics of the Deutsche Bundesbank, there were almost 2,700 companies in China with German investors or a German shareholding in 2017 – about eight times as many as companies in Germany with Chinese investors or a Chinese shareholding. Most of them were sales outlets or representative offices of German companies.

Takeovers of Chinese companies by German investors or majority shareholdings in companies in China are an exception. In the entire period from 2004 to 2018, in only 42 cases did German investors gain far-reaching control over Chinese companies in this way. In the same period, there were 351 majority shareholdings or takeovers in China from all EU countries together. Relative to Germany's economic output, the participation of German investors in these takeovers and investments is well below average. By comparison, investors from the UK in particular, but also from France, were more active in this realm than German investors (cf. figure B 3-12).

Fig. B 3-10

Download data

Total German direct investment in China 2000–2017 in €bn

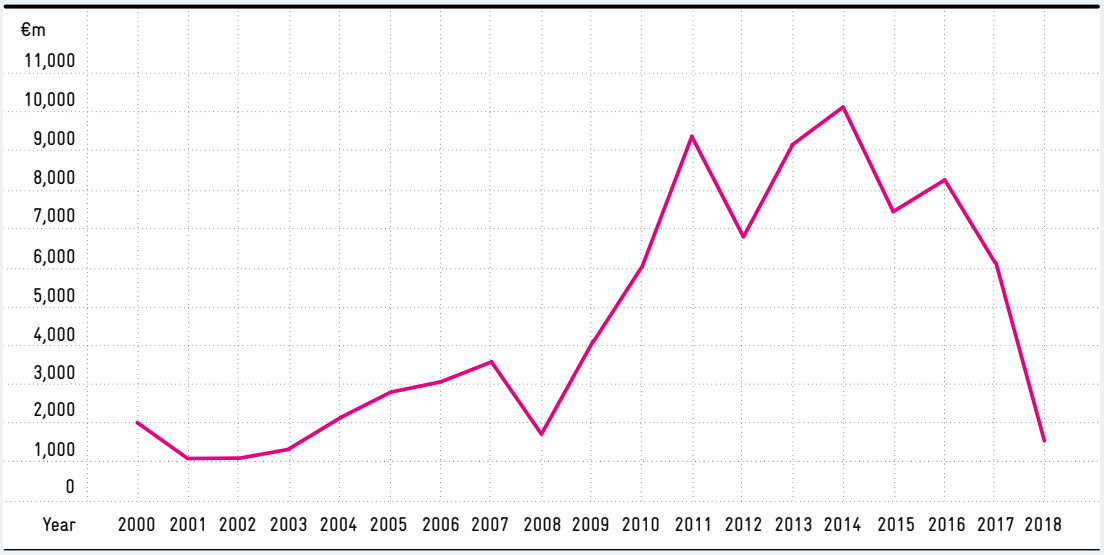


*since 2012: calculated according to the OECD Benchmark Definition, 4th edition.
Source: own diagram following Dürr et al. (2020: 9) based on data from the Deutsche Bundesbank.

Fig. B 3-11

Download data

Total net direct investment by German companies in China 2000–2018 in €m



Source: own diagram following Dürr et al. (2020: 14) based on data from the Deutsche Bundesbank.

Takeovers or majority shareholdings in Chinese companies by German investors between 2004 and 2018 concentrated on the technology sector (cf. figure B 3-13). Over a third were in the area of cutting-edge and high-value technology, and just under a third in non-research-intensive technology.

German FDI in China also flows into joint ventures with Chinese companies. For a long time, the formation of joint ventures was almost the only way for foreign companies to produce in China, and joint ventures remain obligatory in some industries – e.g. the automotive industry, mining, energy and telecommunications, healthcare, publishing and education. However, this obligation is expected to expire in the automotive industry by 2022.[287]

A total of 32 joint ventures involving Chinese and German partners were established in China between 2004 and 2018. This form of cooperation has, however, become noticeably less important in recent times. 20 of the Chinese-German joint ventures were set up before 2008; only 12 additional joint ventures were created in the following ten years.[288]

Current measures to control German direct investment

The activities of German companies in China have hitherto been hampered by restrictions on foreign FDI and by regulations on forced technology transfer.

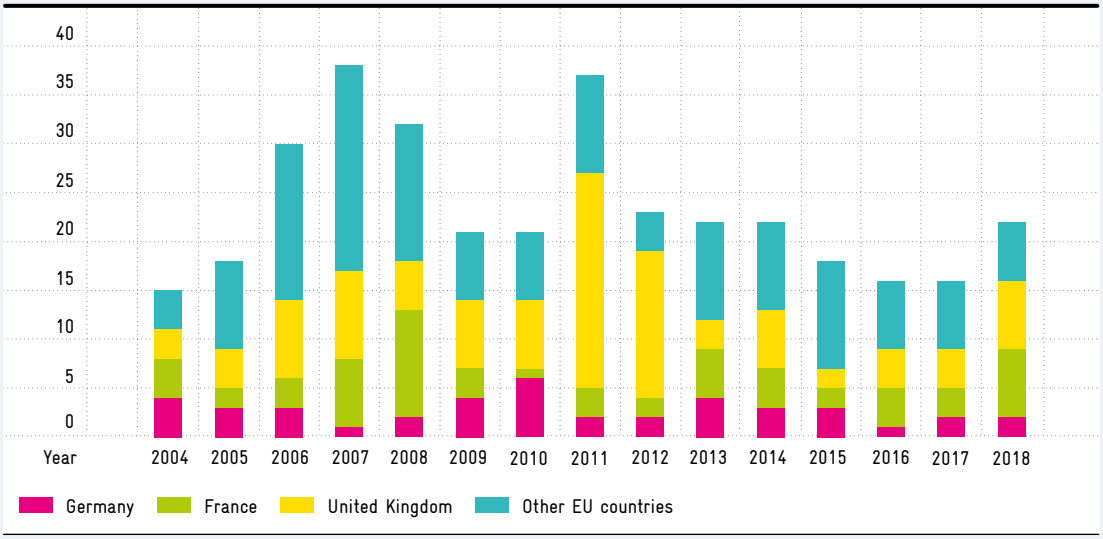
Although China took on far-reaching commitments to open up its markets when it joined the WTO in 2001, so far it has removed restrictions on FDI to only a relatively small degree.[289] The OECD's FDI Regulatory Restrictiveness Index for 2018 rates China's regulatory barriers at 0.251 on a scale from 0 to 1 – with higher index values indicating stricter regulatory restrictions on foreign direct investment. The average index value for all OECD countries was 0.065 – for Germany 0.023.[290]

The Investment Law, which came into force on 1 January 2020, is supposed to remove the regulatory barriers to FDI in China. For the first time, as a matter of principle it provides for equal treatment for foreign and Chinese companies investing in the Chinese market. However, the scope of application of this general rule is substantially limited by a so-called negative list. This list prohibits or restricts the activities of foreign companies in 40 sectors,[291] for example by means of upper limits on shareholdings and the joint-venture obligation.[292]

Fig. B 3-12

Download data

Number of takeovers of Chinese companies by European investors by selected countries of origin 2004–2018

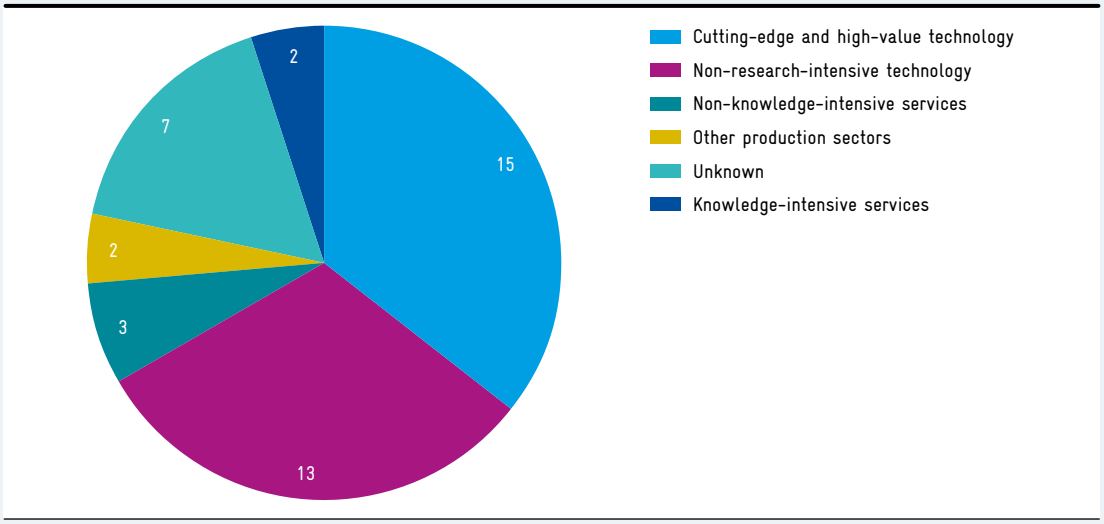


Source: own diagram following Dürr et al. (2020: 47) based on data from Bureau van Dijk, Zephyr database.

Fig. B 3-13

Download data

Number of takeovers of Chinese companies by investors from Germany 2004–2018 by sector



Source: own diagram following Dürr et al. (2020: 48) based on data from Bureau van Dijk, Zephyr database.

The Investment Law also relaxes the rules on the import and export of technologies and reduces the requirements for the transfer of technology. Furthermore, the Chinese authorities are prohibited from forcing the transfer of technology by administrative means. The Chinese government is thus responding to the concerns of foreign investors about forced technology transfer.[293]

Besides the unequal framework conditions for FDI, the insufficient protection of intellectual property rights in China is often criticized, despite some progress in recent years.[294] This problem also affects German investors in China. For example, a survey conducted by the German Chamber of Foreign Trade in China in 2019 concluded that German companies doing business in China still regard the enforcement of intellectual property rights on the Chinese market as a key challenge.[295]

Another challenge increasingly reported by German companies is that the willingness of their employees to spend longer periods in China has been declining. One factor here is that China's image as a destination for secondments has suffered recently. Employees have reservations about internet censorship, state supervision, and the introduction of the so-called social credit system.[296]

Knowledge and technology exchange through direct investment B 3-3

With China's rapidly growing scientific importance, the number of cooperation agreements between German and Chinese academic institutions has increased significantly in recent years. The number of cooperation agreements between German and Chinese tertiary education institutions increased from around 900 in 2013[297] to almost 1,400 in 2019.[298] Non-university research institutions also maintain cooperative relations with China, and some are even represented by their own representative offices in China.[299]

The exchange of students between Germany and China has also intensified. For example, the number of Chinese students in Germany rose from 24,000 in the 2010/11 winter semester to 42,700 in the 2018/19 winter semester.[300] The number of German students in China grew from 4,200 in 2010 to 8,200 in 2014[301] and has remained almost unchanged since then.[302]

The extent of the German-Chinese exchange of scientists has also increased. Although there are no official statistics on the mobility of scientists and academics, it can be estimated using bibliometric methods.[303] In the period from 1996 to 2011, there were fewer than 2,000 publications by German or

Chinese scientists affiliated with an institution in the other country. In the next period covered, from 2006 to 2016, there were already more than 6,000 in total, distributed roughly equally between the two countries.[304] The growing cooperation is also reflected in the number of jointly published research papers.[305] In 2017, 6,800 Sino-German co-publications were counted – a fourfold increase over 2005 (1,700). In terms of joint publications, China is the fourth most important partner country for researchers with German affiliations after the US, the UK and France. Conversely, Germany ranks third for researchers with Chinese affiliations – together with Japan.[306]

Academic cooperation between Germany and China faces a number of challenges. In particular, it is often difficult to select suitable institutional Chinese partners or to initiate and draft cooperation agreements, partly due to a lack of language skills and legal knowledge, partly due to cultural differences.[307] At present, there is no competence centre in Germany that systematically collects and evaluates information on problems with the implementation and design of Sino-German academic cooperation to inform, advise and educate German actors and scientific institutions. Discussions are currently underway between the BMBF, the BMWi, the Federal Foreign Office and the Alliance of Science Organisations on a competence centre for providing advice to scientists in Germany. However, this has not yet been implemented.[308]

In addition, the academic landscape in China is subject to increasing state control and supervision.[309] This also affects the activities of German academic organizations in China. One example of this is the law on the regulation of foreign non-governmental organizations (NGOs), which came into force in 2017. Since then, German non-university research institutions registered on the basis of the NGO law have had to undergo intensive approval procedures that restrict the content of their work and tie up a lot of staff time.[310]

A different kind of challenge in Sino-German scientific cooperation is how to handle dual-use technology.[311] The Chinese government specifically promotes the combination of civil and military research. By contrast, military-related research in Germany is restricted by comprehensive regulations;[312] similarly, goods and technologies that can be used for military purposes are subject to strict export controls. The Federal Government and German scientific organizations are working to raise awareness of the dual-use problem among German scientists through information measures. The intention is to prevent the outflow of dual-use-relevant knowledge abroad – and thus also to China – in the course of international scientific cooperation.[313]

Knowledge and expertise about China in Germany B 3–4

A productive academic and economic exchange with China requires individuals who are well acquainted with Chinese language and culture, as well as with the local markets, institutional framework conditions, and political structures. However, people with such comprehensive expertise about China are hard to find in Germany.[314] This shortcoming affects both science and business. However, it is often easier for large companies to manage this than for other actors such as SMEs or tertiary education institutions.

The declared aim of the recently expired China Strategy 2015–2020 of the BMBF was to create broader-based expertise about China in Germany.[315] In order to achieve this, the BMBF is funding a total of eleven projects between 2017 and 2022 in the context of an initiative called 'Innovative concepts for expanding China expertise at German tertiary education institutions'.[316] Box B 3-14 describes two of these projects in more detail. The initiative aims to equip more people to work in the field of academic and economic exchange with China and thus to expand and consolidate Sino-German- cooperation in science and business.[317] It is currently still unclear whether and within what framework the BMBF is planning to continue this initiative after 2022.

A recent study lists 19 universities and six universities of applied sciences in Germany with a total of 66 courses of study related to China, divided equally between Bachelor's and Master's courses.[318] One third of these courses of study are in classical sinology. Courses in modern sinology and interdisciplinary courses with a focus on China make up another third, respectively.[319] In the past decade, an average of 500 students per year have begun studying sinology. In contrast to other courses of study relating to East Asia (Japanese or Korean studies), where the number of first-year students is rising, the number of first-year students of sinology is stagnating in Germany.[320]

Box B 3-14

Examples of BMBF-funded projects to expand expertise about China at German tertiary education institutions

Expertise about China in Hohenheim (CHIKOH) at the University of Hohenheim

The 'China Expertise in Hohenheim' project at the Faculty of Economics and Social Sciences at the University of Hohenheim, which is funded from October 2017 to September 2020, is designed to promote exchange and networking between German and Chinese universities and industrial partners. The implementation of this objective varies according to the different target groups. For example, students are offered workshops, topic-specific seminars, case-study trips and intercultural training courses. Entrepreneurs and researchers can take part in the annual Hohenheim China Dialogue on intercultural exchange.[321]

The KIT Competence Network for Innovative Cultural Learning and Training in the Environment of University and Research (CuLTURE China) at the Karlsruhe Institute of Technology (KIT)

The 'CuLTURE China' project at KIT is being funded by the BMBF from March 2018 to February 2021. CuLTURE China aims to establish a competence network with a focus on China and, in the course of this, to promote the intercultural and international networking of the actors involved. The project is primarily aimed at students and scientists from the fields of mechanical engineering, electrical engineering and information technology, geo- and environmental sciences, as well as the cross-sectional sciences in the fields of energy and entrepreneurship. The objectives are being implemented, among other things, through the establishment of a Sino-German summer school and tandem field research projects in China and Karlsruhe, and the development of a China expertise centre in Suzhou.[322]

Students of China-oriented fields of study in Germany quite often do not attain good oral, reading and writing skills in Chinese. One reason for this is that curricula – especially in those interdisciplinary courses of study with a focus on China – often do not set particular language level requirements.[323]

Recommendations B 3–5

Create a level playing field for German and Chinese companies

Chinese direct investment in Germany is a relatively recent phenomenon and so far only accounts for a small share of FDI in the country. The sectoral and technological priorities for Chinese investment are influenced by strategic economic and innovation policies such as Made in China 2025 and the Belt and Road Initiative. The empirical evidence available to date does not support the hypothesis that Chinese direct investment in Germany has led to a weakening of the economic performance by the affected companies. Nonetheless, corporate investments and takeovers by Chinese investors in principle involve the risk of political and strategic influence being exerted. At the same time, compared to other countries, China is difficult to access for German direct investments. Technology exchange on equal terms is still challenging, and the protection of intellectual property rights is not always guaranteed.

- The Federal Government should push strongly for equal competitive conditions (i.e. a level playing field) for German and Chinese companies in direct investment.
- The Commission of Experts supports the BMWi's plans to examine corporate takeovers by foreign investors more thoroughly in the field of sensitive technologies. The areas of technology to be included here should be announced first. In addition, clear and transparent auditing criteria need be developed. This should be coordinated with the ongoing European efforts to establish a framework for reviewing foreign direct investment.

Shape scientific cooperation with China for mutual benefit

Science in China serves the political and economic goals of the government. For this reason, German actors involved in scientific cooperation with China are in need of appropriate information and awareness raising in order to ensure benefits on both sides.

- The measures envisaged by the Federal Government to better inform German scientists and make them more aware of the special features of scientific cooperation with China should be intensified and widely disseminated. The dual-use problem, in particular, should be highlighted.
- A central competence centre should be set up to advise German scientists and provide expertise on legal issues relevant to cooperation and research, for example with regard to the protection of intellectual property rights and data. Furthermore, this competence centre should systematically collect and evaluate information on experience and problems with Sino-German cooperation and process it for research and administrative staff at research institutions. The competence centre should also have enough capacity to meet the increased information and consulting needs of SMEs in Sino-German research projects.
- Research and teaching that contribute to the understanding of current political, societal and economic developments in China should be strengthened. In this context, attention should be paid on teaching good Chinese language skills. The current BMBF initiative 'Innovative Concepts for expanding China expertise at German tertiary education institutions' should be further developed, based on sound impact evaluation.
- There should be an intensive and continuous exchange on the framework conditions and prospects of scientific cooperation between Germany and China; this should be coordinated with the European partners. The Commission of Experts recommends that suitable formats for further cooperation should be created soon following the expiry of the BMBF's China Strategy and the termination of the Sino-German Innovation Platform (SGIP).

STRUCTURE AND TRENDS

C

Contents

C 3 Innovation behaviour in the business sector

C 4 Financing research and innovation

C 5 New businesses

C 6 Patents

C 7 Scientific publications

C 8 Production, value added and employment

Overview

Measuring and reporting Germany's performance as a location for research and innovation is an integral part of the annual reports of the Commission of Experts for Research and Innovation. The process involves compiling a number of indicators which allow conclusions to be drawn on the dynamics and efficiency of Germany's research and innovation system. For the sake of clarity, the indicators are divided into eight thematic sets. Based on these indicator sets, the performance of the German research and innovation system is presented both in an intertemporal comparison and compared with the most important competing countries. Furthermore, individual indicators are shown at the Länder level to reveal differences in performance within Germany. Most of the indicators have been drawn from studies on the German innovation system commissioned by the Commission of Experts. In addition to the indicators listed here, these studies also offer comprehensive further material for indicators and analysis. All the studies can be accessed on the Commission of Experts' website and downloaded. The same applies to all the charts and tables in the Report and to the related data sets.

C 1 Education and qualification

Investment in education and a high level of qualification strengthen a country's medium- and long-term innovative capacity and its economic growth. The indicators listed in section C 1 provide information on qualification levels, as well as an overview of Germany's strengths and weaknesses as an innovation location. To facilitate an assessment of Germany's performance at the international level, these findings are compared with figures from other industrialized countries.

C 2 Research and development

Research and development processes are an essential prerequisite for developing new products and services. As a rule, a high level of R&D intensity has positive effects on competitiveness, growth and employment. R&D investments and activities by companies, tertiary education institutions and governments therefore provide an important source of information for assessing a country's technological performance. Section C 2 provides insights into how Germany's R&D activities compare with those of other countries, how much the individual Länder invest, and which sectors of the economy are especially research-intensive.

C 3 Innovation behaviour in the business sector

Innovation activities by companies aim to create competitive advantages. In the case of a product innovation, a new or improved good is launched onto 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 is referred to as a process innovation. Section C 3 depicts the innovation behaviour of the German economy by showing the innovation intensity of industry and knowledge-intensive services, and the percentage of turnover that is generated with new products, in the context of an international comparison.

C 4 Financing research and innovation

The financing of business and, in particular, R&D activities is a key challenge, above all for young, innovative enterprises. Since these companies initially generate little or no turnover, self-financing is often not an option. Debt financing is also difficult, as it is not easy for investors such as banks to assess the success prospects of innovative business start-ups. Alternative methods of corporate financing include raising equity or venture capital, as well as public funding. Section C 4 describes the availability of venture capital and public R&D funds in Germany and other countries.

C 5 New businesses

Business start-ups – especially in research-intensive and knowledge-intensive sectors – challenge established companies with innovative products, processes and business models. The creation of new businesses and the market exit of unsuccessful (or no longer successful) businesses is an expression of innovation competition for the best solutions. The business dynamics described in section C 5 are therefore an important aspect of structural change. Young businesses can open up new markets and leverage innovative ideas – especially in new fields of technology, when new demand trends emerge, and in the early phase of transferring scientific knowledge to the development of new products and processes.

C 6 Patents

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

C 7 Scientific publications

The continuous creation of new knowledge greatly depends on the efficiency of the respective research and science system. Using bibliometric data, section C 7 depicts Germany's performance in this field by international comparison. A country's performance is determined on the basis of its researchers' publications in scientific journals. The perception and importance of these publications is measured by the number of citations.

C 8 Production, value added and employment

Levels of work input and value added in a country's research-intensive and knowledge-intensive sectors – as percentages of the economy as a whole – reflect the economic importance of these sectors and allow conclusions to be drawn on the country's technological performance. Section C 8 depicts the development of value added and productivity in research-intensive industries and knowledge-intensive services by international comparison. The section also provides insights into Germany's global trade position in the fields of research-intensive goods and knowledge-intensive services.

Education and qualification[324] C 1

The percentage of the working population in Germany with tertiary qualifications (ISCED 5+6 and ISCED 7+8) has again risen slightly. In 2018, the figure was 31.7 percent, 0.3 percentage points higher than in the previous year (C 1-1). By contrast, the percentage of people with low qualifications (ISCED 0-2) fell slightly from 10.1 to 10.0 percent. The percentage of people with low qualifications in the total workforce also declined in all reference countries – with the exception of the UK.

The number of new tertiary students as a percentage of the relevant age group (C 1-2) in Germany was 60 percent in 2017, the same level as in 2016. The adjusted rate for the under-25s and excluding international first-year students also remained constant at 45 percent. For China, data according to ISCED 2011 were available for the first time in 2017.

The rate of qualified school-leavers, i.e. the number of school-leavers qualified for higher education as a percentage of the relevant age group, again fell slightly and was 50.6 percent in 2018 (C 1-3). There were 432,414 qualified school-leavers in 2018. The Standing Conference of the Ministers of Education and Cultural Affairs (Kultusministerkonferenz, KMK) expects an increase in the ratio of qualified school-leavers in 2019. According to the KMK's projections, the number of qualified school-leavers will remain largely constant up to 2030.

In 2018, the number of first-time graduates (C 1-4) fell slightly compared to the previous year from 311,441 to 303,155. The proportion of female first-time graduates rose slightly to 53.0 percent. At the same time, the percentage of first-time graduates who completed their degree at a university fell again – from 53.9 to 53.0 percent.

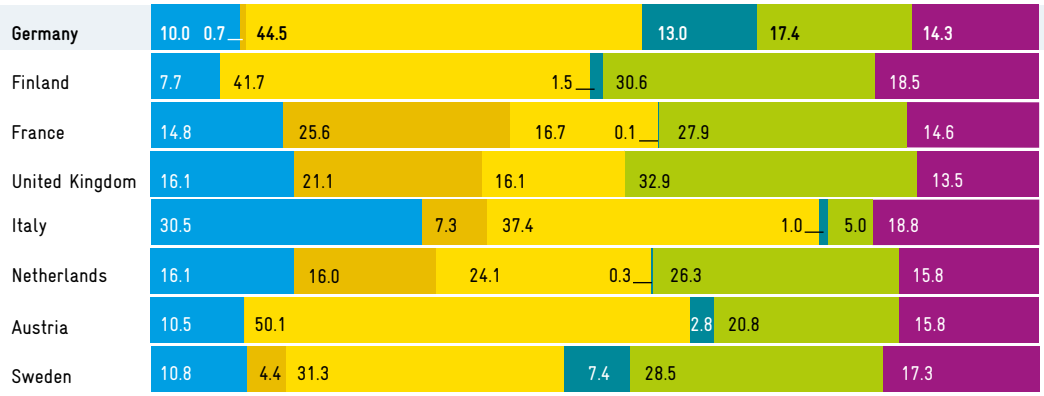
At 92,508, the number of students without German citizenship who gained their university entrance qualifications in Germany (Bildungsinländer) was almost the same in the 2018/19 winter semester as in the 2017/18 winter semester. On the other hand, the total number of foreign students in Germany increased by more than five percent compared to the previous year (C 1-5). In the 2018/19 winter semester, the number of students without German citizenship who gained their university entrance qualification abroad (Bildungsausländer) enrolled at German tertiary education institutions exceeded 300,000 for the first time. Their number was thus 38 percent higher than in the winter semester five years earlier.

The further-training rate among persons aged between 25 and 64 (C 1-6) fell slightly compared to 2017 and stood at 4.9 percent in 2018. The further-training rates of low- and medium-skilled gainfully employed people each fell by 0.2 percentage points. In 2017, the rate of corporate participation in further training reached 53.0 percent, 0.2 percentage points down on the previous year.

Fig. C 1-1

Download data

Qualification levels of gainfully employed persons in selected EU countries in 2018 as percentages[1)]



Classification of the ISCED qualification levels.[2)]

- ISCED 0-2: (Pre)primary and lower secondary education
- ISCED 3*: General and vocational upper secondary education without direct access to tertiary education
- ISCED 3**: General and vocational upper secondary education with direct access to tertiary education
- ISCED 4: Post-secondary non-tertiary education, (Abitur school-leaving examination and apprenticeship)
- ISCED 5+6: Short, career-related tertiary education (2 to less than 3 years), Bachelor's degree, training as a master craftsman or technician or equivalent vocational school qualification.
- ISCED 7+8: Master's degree, doctoral degree or equivalent qualification

[1)] Figures that do not add up to 100 percent: graduation level unknown.
[2)] UNESCO uses the ISCED classification of educational levels as standards for international comparisons of country-specific education systems. They are also used by the OECD.
Source: Eurostat, European Labour Force Survey. Calculation by CWS in Gehrke et al. (2020a).

C

Number of new tertiary students as a percentage of the relevant age group in selected OECD countries and China 2006–2017

Tab. C 1-2

Download data

University entry rate: number of new tertiary students as a percentage of the relevant age group.

OECD countries[1]	2006	2009	2012	2013[2]	2014[2]	2015[2]	2016[2]	2017[2]	2013[3]	2014[3]	2015[3]	2016[3]	2017[3]
Belgium	35	31	34	67	67	69	72	76	54	57	59	62	67
China	–	17	18	–	–	–	–	67	–	–	–	–	–
Germany	**35**	**40**	**53**	**59**	**64**	**63**	**60**	**60**	**45**	**48**	**48**	**45**	**45**
Finland	76	69	66	55	53	56	58	59	41	40	42	42	43
United Kingdom	57	61	67	58	61	69	64	74	42	44	50	48	53
Italy	56	50	47	42	44	46	48	50	–	–	41	41	43
Japan	45	49	52	–	80	80	80	79	–	–	–	–	–
Sweden	76	68	60	56	62	62	62	63	40	42	41	40	41
Switzerland	38	41	44	–	–	–	–	–	–	36	47	47	47
USA	64	70	71	52	52	52	52	49	47	47	46	46	44
OECD average	**56**	**59**	**58**	**67**	**68**	**66**	**66**	**65**	**50**	**51**	**48**	**49**	**50**

[1] To date, no ISCED 2011 figures are available for France or South Korea. These countries are therefore not included in the table. Three European OECD countries have been added instead: Belgium, Finland and Italy.

[2] The table shows the university entry rates according to the ISCED classification for levels 5, 6, 7 and 8. Please note: figures from 2013 and later were compiled according to ISCED 2011, figures before 2013 according to ISCED 1997; this table is therefore not comparable with previous years. ISCED 2011 used here has nine levels, while ISCED 1997 had only seven. ISCED 2011 distinguishes between four instead of two levels in the field of tertiary-level education (ISCED 1997: Levels 5A and 6; ISCED 2011: Levels 5 to 8) and enables a distinction to be made between 'general and vocational upper secondary education without direct access to tertiary education (ISCED 3*)' on the one hand and 'general and vocational upper secondary education with direct access to tertiary education (ISCED 3**)' on the other.

[3] Adjusted rate for under-25s, excluding new international tertiary students.

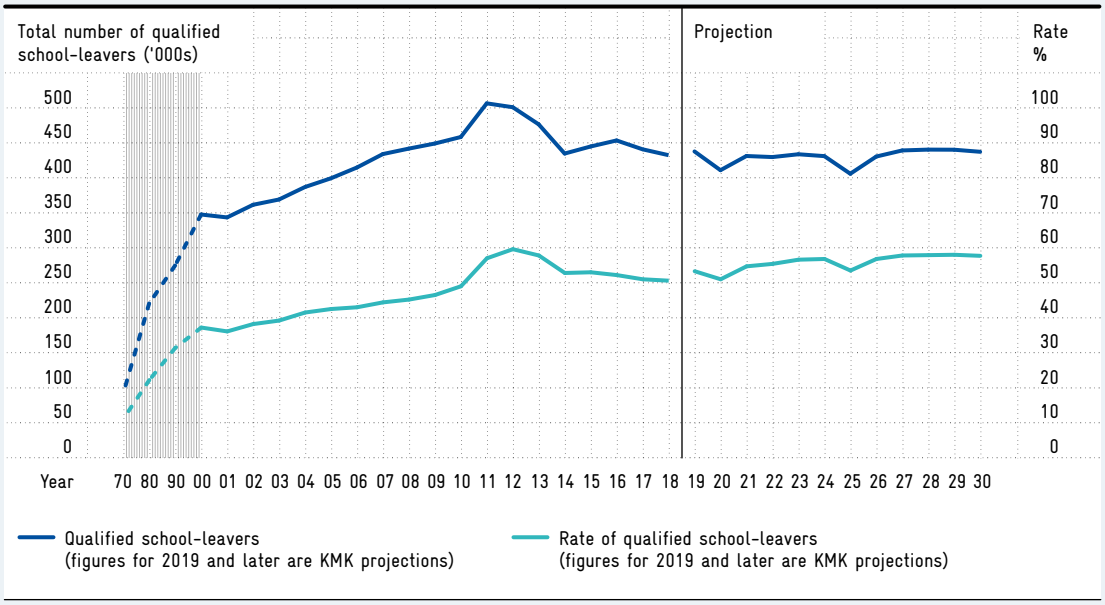
Sources: OECD (ed.): Education at a glance. OECD indicators, various years in Gehrke et al. (2020a).

Fig. C 1-3

Download data

School-leavers qualified for higher education in Germany 1970–2030 (figures for 2019 and later are projections)

School-leavers qualified for higher education: either with a 'general' or a 'technical' school-leaving certificate* (in Germany Abitur).
Rate of qualified school-leavers: number of school-leavers qualified for higher education as a percentage of the relevant age group.



* Since 2013, actual figures no longer include school leavers who have passed the school part of the 'technical' Abitur.
Source of actual figures: Statistisches Bundesamt (Federal Statistical Office) in Gehrke et al. (2020a).
Source of forecast figures: statistical publications by The Standing Conference of the Ministers of Education and Cultural Affairs (Kultusministerkonferenz, KMK) in Gehrke et al. (2020a).

C

Number of first-time graduates and subject-structure rate[1] 2010–2018

Tab. C 1-4

Download data

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

	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total number of graduates[2]	**294,330**	**307,271**	**309,621**	**309,870**	**313,796**	**317,102**	**315,168**	**311,441**	**303,155**
Percentage of women	52.1	51.4	51.3	51.5	51.2	51.1	52.0	52.6	53.0
Percentage of graduates from universities	62.0	62.1	61.3	59.9	59.0	56.8	54.7	53.9	53.0
Humanities	**38,385**	**39,435**	**38,444**	**38,247**	**38,788**	**37,135**	**34,886**	**32,205**	**30,491**
Percentage of subject group	13.0	12.8	12.4	12.3	12.4	11.7	11.1	10.3	10.1
Legal, economics and social sciences	**119,289**	**122,294**	**122,239**	**123,171**	**125,628**		**132,737**	**134,605**	**131,832**
Percentage of subject group	40.5	39.8	39.5	39.7	40.0	40.5	42.1	43.2	43.5
Human medicine, health sciences	**15,222**	**15,686**	**15,856**	**16,534**	**17,331**	**17,935**	**19,521**	**20,308**	**20,101**
Percentage of subject group	5.2	5.1	5.1	5.3	5.5	5.7	6.2	6.5	6.6
Agriculture, forestry, and food sciences, veterinary medicine	**7,125**	**7,521**	**7,345**	**7,158**	**7,008**	**7,442**	**6,978**	**7,148**	**7,252**
Percentage of subject group	2.4	2.4	2.4	2.3	2.2	2.3	2.2	2.3	2.4
Arts, art history	**11,820**	**12,525**	**12,866**	**12,542**	**11,913**	**11,514**	**11,268**	**11,119**	**10,892**
Percentage of subject group	4.0	4.1	4.2	4.0	3.8	3.6	3.6	3.6	3.6
Mathematics, natural sciences	**32,800**	**34,096**	**32,793**	**31,665**	**31,635**	**30,001**	**28,081**	**26,261**	**25,677**
Percentage of subject group	11.1	11.1	10.6	10.2	10.1	9.5	8.9	8.4	8.5
Engineering	**65,621**	**71,128**	**75,697**	**77,049**	**78,018**	**81,300**	**78,552**	**76,133**	**73,849**
Percentage of subject group	22.3	23.1	24.4	24.9	24.9	25.6	24.9	24.4	24.4

[1] The Federal Statistical Office's new subject-group classification has been in use since the 2015/16 winter semester. Apart from minor changes, such as renaming of some study subjects or the merger of veterinary medicine with agriculture, forestry and food sciences, there were two major re-classifications. The subject group legal, economics and social sciences now also includes psychology, education and special needs education, which used to be assigned to language and cultural sciences (now called humanities). Since the changeover, computer science has been counted under engineering and not, as previously, as part of mathematics, natural sciences. Furthermore, a new area of study called materials science and materials engineering was introduced under engineering; materials science and materials engineering were previously assigned to mechanical engineering. All the time series have been retrospectively reclassified to fit the new system of subjects. This avoids breaks in the time series. However, comparisons with the tables in the EFI Reports up until 2017 are now only possible to a limited extent.

[2] Graduates with first academic degree.

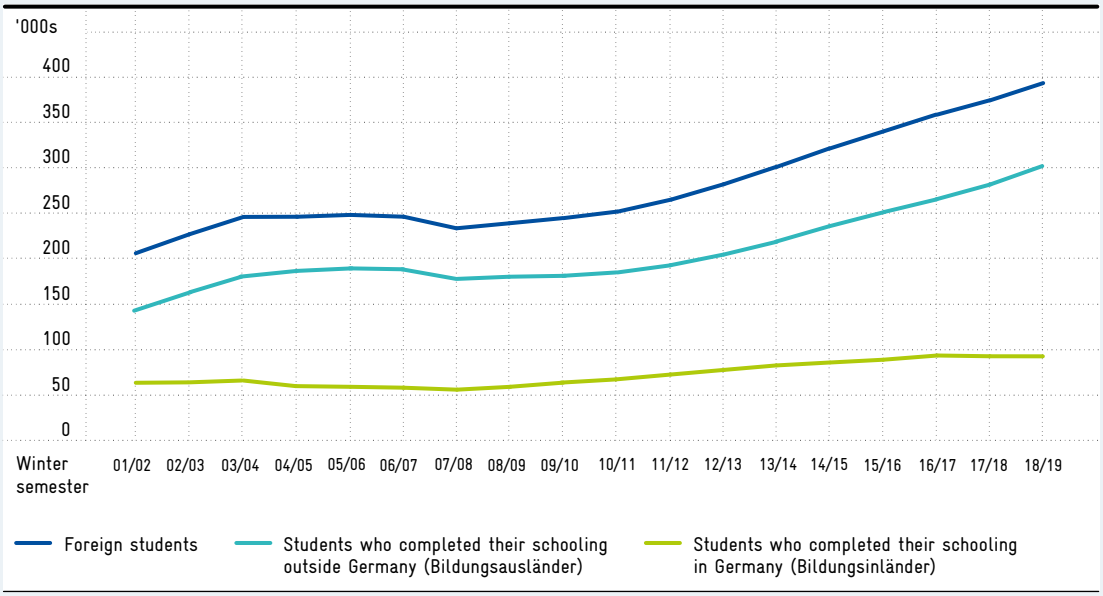
Source: Statistisches Bundesamt (Federal Statistical Office) and research by DZHW-ICE in Gehrke et al. (2020a).

Fig. C 1-5

Download data

Foreign students at German tertiary education institutions 2001–2019

Foreign students are defined as persons without German citizenship. They can be divided into students who obtained their higher-education entrance qualification in Germany (Bildungsinländer), and those who obtained this qualification abroad (Bildungsausländer).



Source: Statistisches Bundesamt (Federal Statistical Office) and research by DZHW-ICE in Gehrke et al. (2020a).

C

Participation of individuals and companies in further training 2008–2018 as percentages

Tab. C 1-6

Download data

Individual further-education rate: percentage of people who had participated in a further-education measure in the last four weeks prior to the time of the survey. Corporate participation in further training: percentage of companies where employees were released for training or whose training costs were paid.*

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
a) Individual further-education rate	**5.5**	**5.0**	**4.9**	**4.9**	**5.1**	**4.9**	**4.8**	**4.9**	**5.2**	**5.0**	**4.9**
Gainfully employed persons	**6.4**	**5.8**	**5.6**	**5.6**	**5.9**	**5.6**	**5.5**	**5.5**	**5.8**	**5.4**	**5.3**
low (ISCED 0-2)	1.7	1.4	1.3	1.0	1.4	1.4	1.3	1.2	1.5	1.5	1.3
medium (ISCED 3-4)	4.4	4.2	3.9	3.9	4.1	3.9	4.2	4.3	4.5	4.2	4.0
high (ISCED 5-8)	12.2	10.6	10.5	10.3	10.6	10.1	9.4	9.3	9.7	8.9	8.9
Unemployed persons	**4.9**	**4.3**	**3.9**	**4.6**	**3.8**	**3.6**	**3.7**	**3.7**	**4.2**	**5.3**	**5.1**
low (ISCED 0-2)	2.4	2.7	3.5	3.6	3.1	2.9	2.8	2.6	3.3	5.1	4.9
medium (ISCED 3-4)	5.3	4.0	3.2	4.0	3.6	3.4	3.3	3.4	3.6	4.3	4.2
high (ISCED 5-8)	8.1	8.4	8.3	10.0	6.6	5.4	6.4	6.3	7.2	8.6	7.7
Inactive persons	**2.3**	**1.9**	**2.0**	**1.9**	**1.6**	**1.8**	**1.8**	**2.0**	**2.4**	**3.2**	**2.9**
low (ISCED 0-2)	1.4	1.8	1.6	1.5	1.4	1.4	1.3	1.7	2.5	4.0	3.8
medium (ISCED 3-4)	1.8	1.5	1.8	1.9	1.4	1.5	1.6	1.6	1.8	2.2	2.0
high (ISCED 5-8)	5.4	3.4	3.6	2.7	2.8	3.5	3.4	3.7	4.4	4.9	4.2
b) Corporate participation in further training[1)]	**49.0**	**44.6**	**44.1**	**52.6**	**53.1**	**52.1**	**53.6**	**52.8**	**53.2**	**53.0**	**–**
By sector											
Knowledge-intensive manufacturing	65.1	52.6	55.9	62.9	65.5	66.7	69.9	70.6	64.0	65.0	–
Non-knowledge-intensive manufacturing	37.8	32.5	33.3	41.2	43.2	41.8	43.0	44.5	46.3	45.4	–
Knowledge-intensive services	68.3	58.7	57.1	68.7	67.2	67.4	67.0	67.5	69.2	66.1	–
Non-knowledge-intensive services	39.4	38.0	37.5	44.9	45.3	44.3	46.0	43.8	43.7	45.2	–
Non-commercial economy	53.8	51.9	51.2	59.0	60.3	58.4	61.9	60.1	59.3	59.3	–
By company size											
< 50 employees	46.9	42.5	41.8	50.5	50.9	49.8	51.4	50.5	50.8	50.6	–
50–249 employees	86.7	81.3	83.3	90.8	89.7	90.1	90.8	89.3	89.5	89.0	–
250–499 employees	95.9	92.0	93.3	95.9	96.5	97.0	96.9	96.8	96.4	96.0	–
≥ 500 employees	97.8	96.0	97.9	98.4	97.8	99.1	99.1	97.1	97.9	97.2	–

* Question in the IAB Establishment Panel: "Were employees released to participate in in-house or external training measures and/or were the costs of training measures paid wholly or in part by the establishment?" For ISCED cf. C 1-1.
Population a): All persons aged between 25 and 64.
Population b): All establishments with at least one employee covered by social security insurance.
[1)] The data for corporate participation in further training in 2018 were not available by the editorial deadline.
Source a): European Labour Force Survey (special evaluation). Calculations by CWS in Gehrke et al. (2020a). Data from 2016 onwards relating to unemployed and inactive persons are only comparable with previous years to a limited extent due to methodological adjustments and stricter confidentiality regulations.
Source b): IAB Establishment Panel (special evaluation). Calculations by CWS in Gehrke et al. (2020a).

C 2 Research and development[325]

Statistics about expenditure on research and development (R&D) indicate the extent of activities aimed at generating new ideas. R&D intensity – i.e. R&D expenditure as a percentage of gross domestic product (in the case of countries) or turnover (in the case of companies) – provides information on the willingness to invest in R&D; the distribution of R&D expenditure across sectors and industries indicates the main priorities of research and development activity.

R&D intensity (C 2-1) in Germany was 3.13 percent in 2018, compared to 2.62 percent in 2008. It has thus increased by 0.51 percentage points over the past ten years. R&D intensity in China and Switzerland rose to a similar extent in the period 2008 to 2017 (China by 0.71 percentage points, Switzerland by 0.64 percentage points) – no data are yet available for 2018. By far the biggest increase was recorded by South Korea where R&D intensity grew by 1.43 percentage points from 3.12 to 4.55 percent between 2008 and 2017.

Germany's budget estimate for civil R&D (C 2-2) reached an index value of 176 percent in 2018. This means that the amount specified in the German national budget for financing R&D increased by 76 percent between 2008 and 2018. The budget estimate for civil R&D also increased sharply in Sweden, Switzerland and South Korea.

The distribution of gross domestic expenditure on R&D by performing sector (C 2-3) shows that the percentage of R&D expenditure carried out in the public sector declined or stagnated between 2007 and 2017 in all the countries shown. The share of expenditure fell particularly sharply in China (from 19.2 to 15.2 percent) and in France (from 16.4 to 12.7 percent). In Germany, the share of spending on R&D conducted in the public sector fell slightly from 13.9 to 13.5 percent during this period.

The R&D intensity of Germany's Länder (C 2-4) increased markedly between 2007 and 2017 – in all Länder without exception. Baden-Württemberg spent by far the highest percentage of its gross domestic product on R&D. It had already reached an R&D intensity of 4.16 percent in 2007 and increased this to 5.63 percent in 2017 – the highest growth rate of all the Länder.

Internal corporate expenditure on R&D (C2-5) reached €68.8 billion in 2017. Spending in the vehicle construction field alone amounted to €27.4 billion, while the electrical/ electronic and mechanical engineering sectors accounted for €10.4 billion and €7.1 billion respectively.

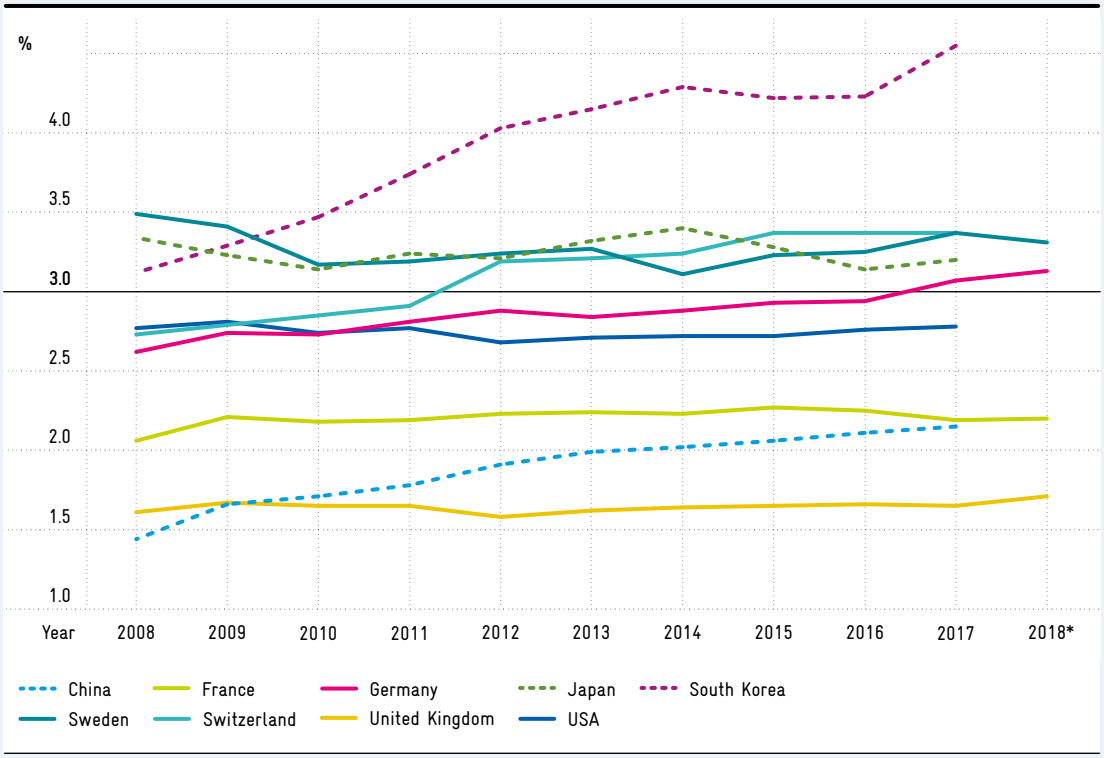
The indicator 'internal corporate R&D expenditure as a percentage of turnover from the company's own products' (C 2-6) documents an increase in average R&D intensity in the manufacturing sector for 2016, 2017 and 2018. This figure rose from 3.5 percent in 2016 to 3.8 percent in 2018.

R&D intensity in selected OECD countries and China 2008–2018 as percentages

Fig. C 2-1

Download data

R&D intensity: percentage of an economy's gross domestic product (GDP) spent on research and development.



*Preliminary figures for 2018.

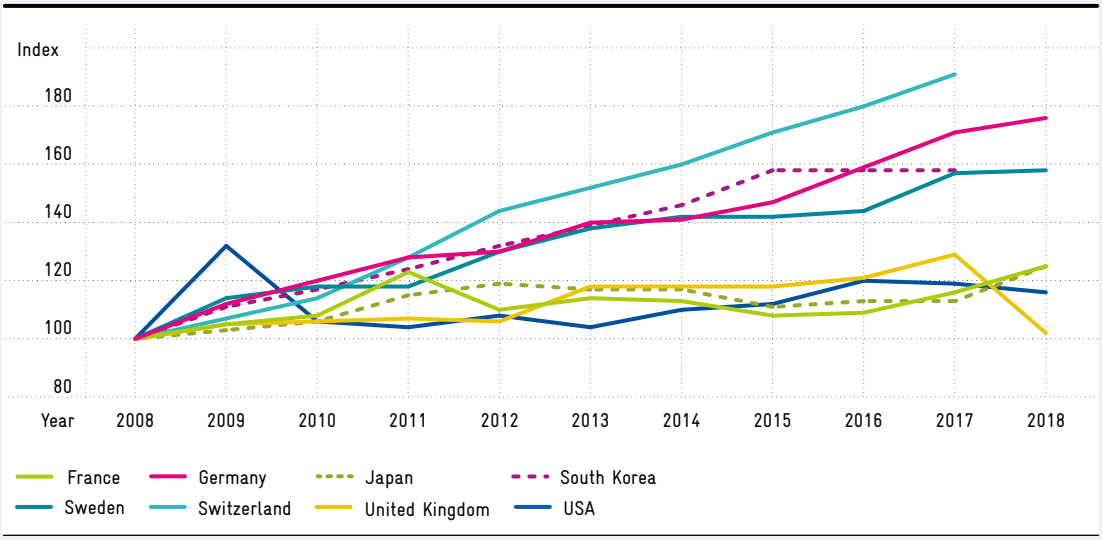
Source: OECD, Eurostat. Calculations and estimates by CWS in Gehrke et al. (2020b).

Fig. C 2-2

Download data

State budget estimates for civil R&D 2008–2018

R&D budget estimates: the chart shows the amounts set aside in the budget to finance R&D.



Index: 2008 = 100, data partially based on estimates.
Source: OECD, Eurostat. Calculations and estimates by CWS in Gehrke et al. (2020b).

Tab. C 2-3

Download data

Distribution of gross domestic expenditure on R&D (GERD) by performing sector in selected OECD countries and China in 2007 and 2017

Gross domestic expenditure on R&D (GERD) in the business sector, tertiary education, the public sector and private non-profit organizations.

	2007					2017				
		of which (%) carried out by					of which (%) carried out by			
Countries	GERD in US$m	Business sector	Tertiary education institutions	Public sector	Private non-profit	GERD in US$m	Business sector	Tertiary education institutions	Public sector	Private non-profit
France	44,179	63.0	19.5	16.4	1.2	64,672	65.0	20.7	12.7	1.7
Germany	**73,358**	**70.0**	**16.1**	**13.9**	**-**	**131,339**	**69.1**	**17.4**	**13.5**	**-**
Japan	147,484	77.9	12.6	7.8	1.7	170,901	78.8	12.0	7.8	1.4
South Korea	40,639	76.2	10.7	11.7	1.5	90,980	79.4	8.5	10.7	1.4
Sweden	12,089	73.0	21.9	4.9	0.2	17,201	71.3	24.9	3.6	0.1
Switzerland [1)]	10,017	73.6	23.8	0.8	1.7	18,738	69.4	27.6	0.8	2.2
United Kingdom	35,211	62.5	26.1	9.2	2.2	49,345	67.6	23.7	6.5	2.2
USA	380,316	70.8	13.4	11.8	4.0	543,249	73.1	13.0	9.7	4.1
China	124,199	72.3	8.5	19.2	-	495,981	77.6	7.2	15.2	-

Data from 09/2019: [1)] 2006 instead of 2007.
Germany and China: private non-profit organizations included under 'public sector'.
Source: OECD, Eurostat. Calculations by CWS in Gehrke et al. (2020b).

R&D intensity of Germany's Länder in 2007 and 2017 as percentages

Tab. C 2-4

Download data

R&D intensity: Länder expenditure on research and development as a percentage of their gross domestic product, broken down by performing sector.

	2007				2017			
Länder	Total	Business sector	Public sector	Tertiary education institutions	Total	Business sector	Public sector	Tertiary education institutions
Baden-Württemberg	4.16	3.38	0.37	0.40	5.63	4.71	0.41	0.51
Bavaria	2.81	2.21	0.25	0.35	3.09	2.34	0.31	0.43
Berlin	3.02	1.25	1.00	0.77	3.40	1.37	1.19	0.84
Brandenburg	1.22	0.32	0.64	0.26	1.68	0.57	0.74	0.37
Bremen	2.14	0.85	0.71	0.58	2.75	0.88	1.10	0.76
Hamburg	1.80	1.07	0.40	0.33	2.14	1.24	0.38	0.53
Hesse	2.49	2.03	0.15	0.31	2.91	2.20	0.28	0.43
Mecklenburg-Western Pomerania	1.38	0.40	0.56	0.42	1.79	0.58	0.64	0.58
Lower Saxony	2.41	1.67	0.33	0.41	3.10	2.20	0.37	0.53
North Rhine-Westphalia	1.70	1.07	0.25	0.38	2.09	1.23	0.30	0.55
Rhineland-Palatinate	1.78	1.32	0.14	0.32	2.43	1.78	0.18	0.47
Saarland	1.03	0.42	0.28	0.33	1.74	0.86	0.36	0.53
Saxony	2.58	1.34	0.66	0.58	2.78	1.21	0.79	0.78
Saxony-Anhalt	1.17	0.35	0.42	0.40	1.49	0.41	0.51	0.57
Schleswig-Holstein	1.18	0.53	0.31	0.34	1.55	0.83	0.34	0.38
Thuringia	1.87	0.96	0.43	0.48	2.19	1.10	0.48	0.61
Germany	**2.44**	**1.71**	**0.34**	**0.39**	**3.03**	**2.10**	**0.41**	**0.52**

Source: SV Wissenschaftsstatistik and statistical offices of the Federal Government and the Länder in Gehrke et al. (2020b).

Tab. C 2-5

Download data

Internal corporate R&D expenditure by origin of funds, economic sector, company size and technology category in 2017

Internal R&D: R&D 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 funded by			
		Business sector	Public sector	Other domestic entities	Foreign entities
	in 1,000 Euro	as percentages			
All researching companies	**68,787.323**	**90.4**	**3.2**	**0.1**	**6.3**
Manufacturing	58,493.502	91.6	1.8	0.1	6.5
Chemical industry	4,065.084	91.1	1.4	0.0	7.5
Pharmaceutical industry	4,630.940	80.2			18.9
Plastics, glass and ceramics	1,468.445	94.9	2.7	0.2	2.2
Metal production and processing	1,499.201	80.2	8.3	0.3	11.2
Electrical engineering/electronics	10,431.420	89.7	2.7	0.0	7.6
Mechanical engineering	7,116.706	95.6	2.3	0.1	2.0
Vehicle construction	27,431.531	93.7	1.0	0.2	5.2
Other manufacturing industries	1,850.175	93.0	4.3	0.1	2.6
Remaining sectors	10,293.822	86.1	9.5	0.1	4.2
fewer than 100 employees	3,153.908	70.8	21.6	0.5	7.1
100 to 499 employees	5,731.228	84.5	8.0	0.2	7.3
500 to 999 employees	4,098.690	88.5	6.2	0.1	5.2
1,000 employees and more	55,803.497	92.3	1.4	0.1	6.2
Technology categories in industry					
Cutting-edge technology (> 9 percent of costs/turnover spent on R&D)	14,263.536	84.5	3.4	0.0	12.0
High-value technology (3–9 percent of costs/turnover spent on R&D)	38,768.519	94.3	0.9	0.1	4.6

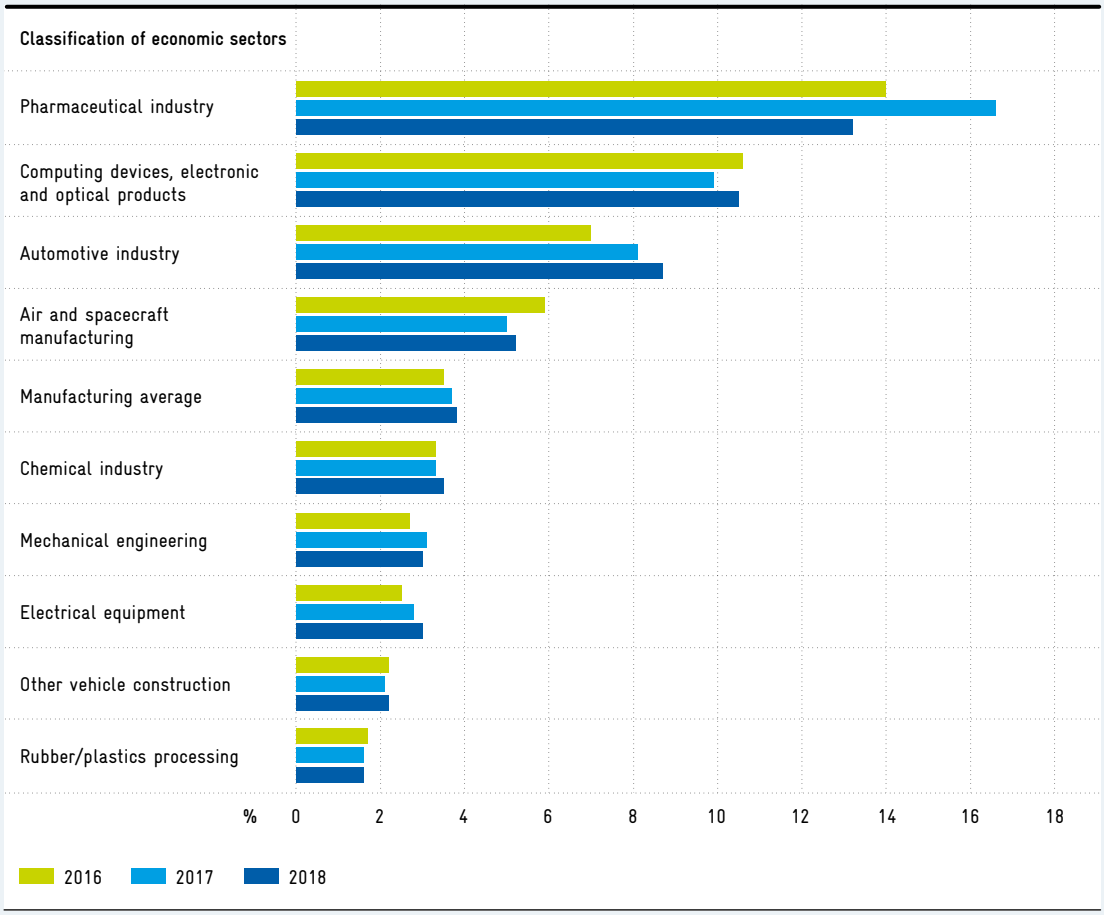
Source: SV Wissenschaftsstatistik in Gehrke et al. (2020b).

Fig. C 2-6

Download data

Internal corporate R&D expenditure as a percentage of turnover from the company's own products[1] 2016–2018

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



[1] Figures net, without input tax.

Source: SV Wissenschaftsstatistik, Statistisches Bundesamt (Federal Statistical Office), corporate results for Germany. Calculations by CWS in Gehrke et al. (2020b).

C 3 Innovation behaviour in the business sector

The biennial Europe-wide Community Innovation Surveys (CIS) provide the underlying data for international comparisons of the business sector's innovation behaviour (C 3-1).[326] Coordinated by Eurostat and based on a harmonized methodology, the CISs are conducted in all EU member states and a number of other European countries. The CISs are based on a largely uniform questionnaire and directed at businesses with ten or more employees in the manufacturing industry and selected services sectors.

The current analysis relates to 2016 (CIS 2016). In that year, the innovation intensity of the research-intensive industries in Germany amounted to 7.4 percent. It was thus higher than that of most reference countries. However, Sweden and Denmark recorded slightly higher innovation intensities at 8.2 and 7.8 percent in their respective research-intensive industries.

The data on innovation behaviour in the German business sector in the period 2003 to 2018, as shown in charts C 3-2 and C 3-3, are based on the Mannheim Innovation Panel (MIP), an annual innovation survey that has been conducted by the ZEW – Leibniz Centre for European Economic Research (ZEW) since 1993.[327] Data from the MIP constitute the German contribution to the CIS. In addition to the data to be reported to Eurostat, the MIP also includes data on companies with five to nine employees.

Innovation intensity (C 3-2) has shown only minor fluctuations in recent years in all the industrial and business-oriented services sectors reviewed. Recently, however, it increased relatively strongly in knowledge-intensive services. At 6.3 percent in 2018, innovation intensity here was 1.1 percentage points higher than in the previous year.

In 2018, the percentage of turnover generated by new products (C 3-3) declined slightly compared to the previous year in R&D-intensive industry (from 34.5 to 33.0 percent), in other industry (from 8.4 to 7.6 percent) and in knowledge-intensive services (from 13.4 to 12.8 percent). Only other services recorded an increase in the ratio (from 6.2 to 7.3 percent).

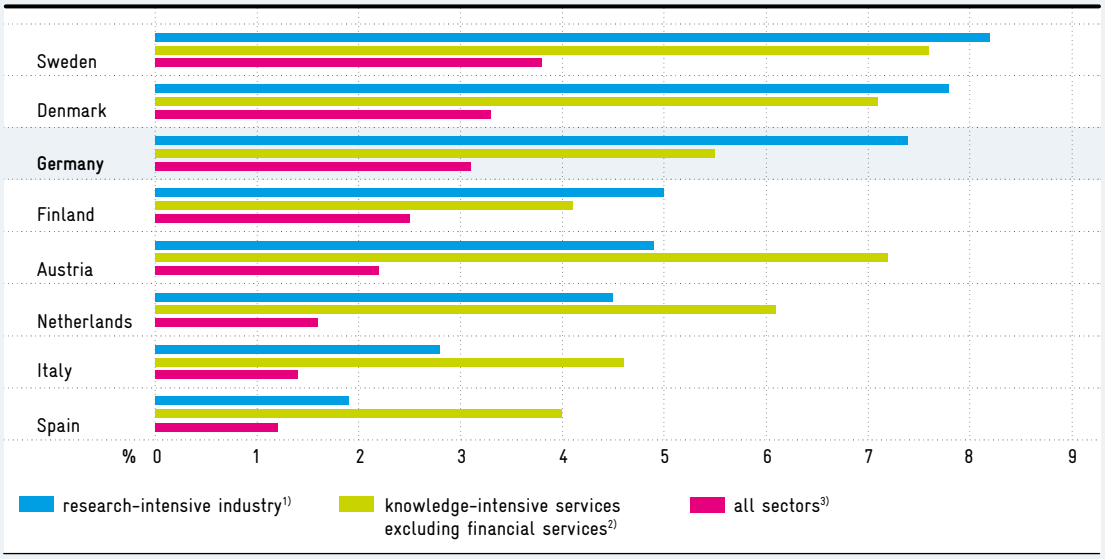
Standardization is an important factor in the commercialization of innovative technologies. At the international level, standards are developed by the committees of the International Organization for Standardization (ISO). By participating in these committees, a country can make a significant impact on global technical infrastructures (C3-4).[328] German companies have been involved in the work of the ISO considerably more frequently than representatives of other countries[329] From 2009 to 2019, Japan and above all China significantly increased the number of ISO secretariats run by their representatives.

Innovation intensity by European comparison in 2016 as percentages

Fig. C 3-1

Download data

Innovation intensity: innovation expenditure by companies as a percentage of their total turnover.



1) Research-intensive industry: divisions 19-22, 25-30 of WZ classification. Since data are not available for all sectors in all countries, the definition of research-intensive industries used in the European comparison differs from the definition normally used by the EFI.
2) Knowledge-intensive services excluding financial services: divisions 58-63, 71-73 of WZ classification. Since data are not available for all sectors in all countries, the definition of knowledge-intensive services used in the European comparison differs from the definition normally used by the EFI.
3) All sectors: divisions 5-39, 46, 49-53, 58-66, 71-73 of WZ classification.

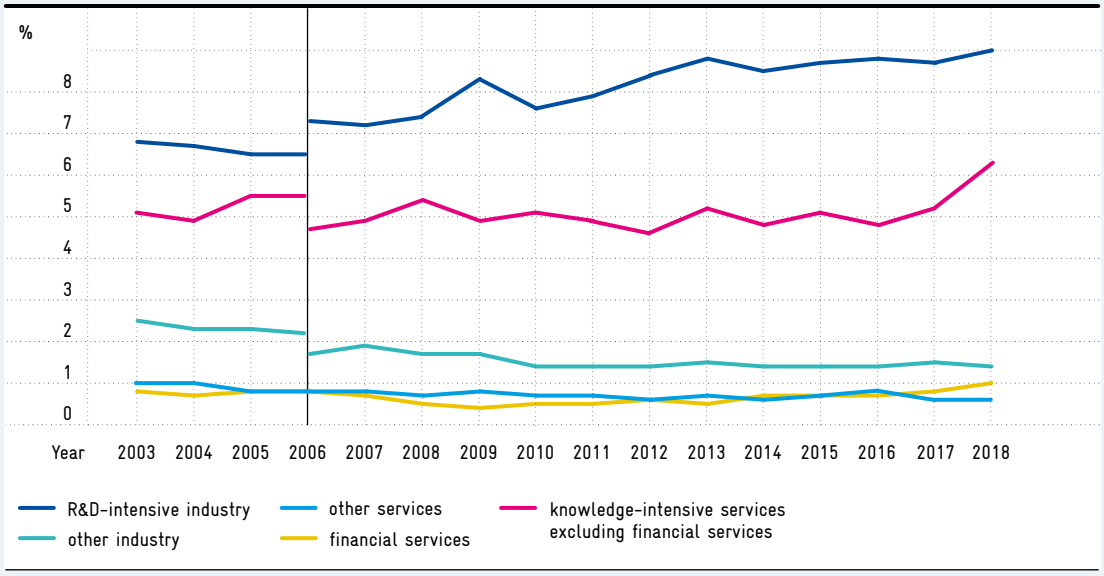
Source: Eurostat, Community Innovation Surveys 2016. Calculations by ZEW (ZEW – Leibniz Centre for European Economic Research).

Innovation intensity in industry and business-oriented services in Germany 2003-2018 as percentages

Fig. C 3-2

Download data

Innovation intensity: innovation expenditure by companies as a percentage of their total turnover.



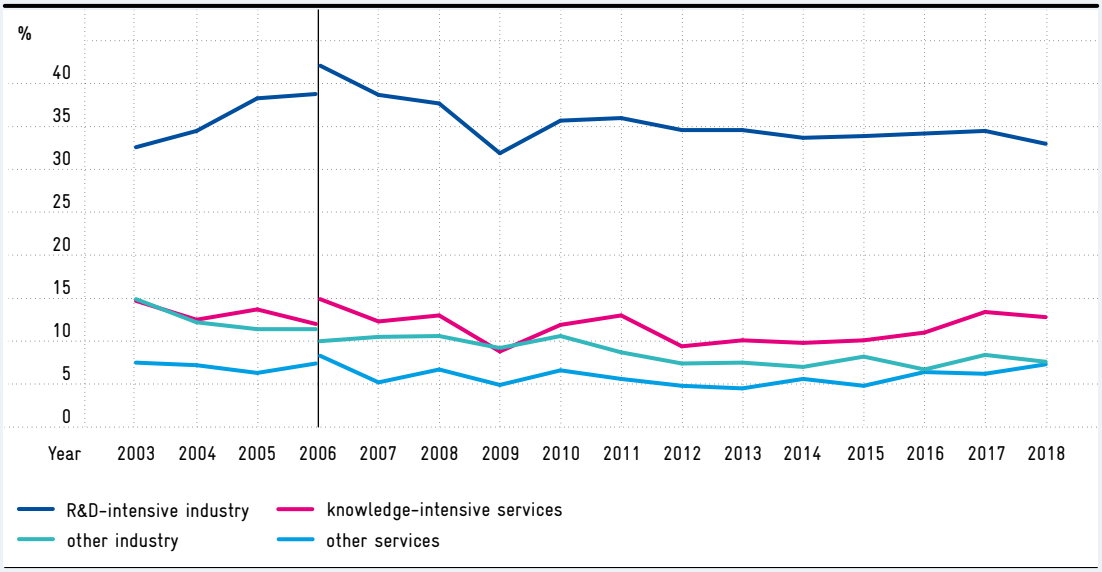
2006: break in time series.

Source: Mannheim Innovation Panel. Calculations by ZEW (ZEW – Leibniz Centre for European Economic Research).

Fig. C 3-3

Download data

Percentage of turnover generated by new products in industry and business-oriented services 2003–2018

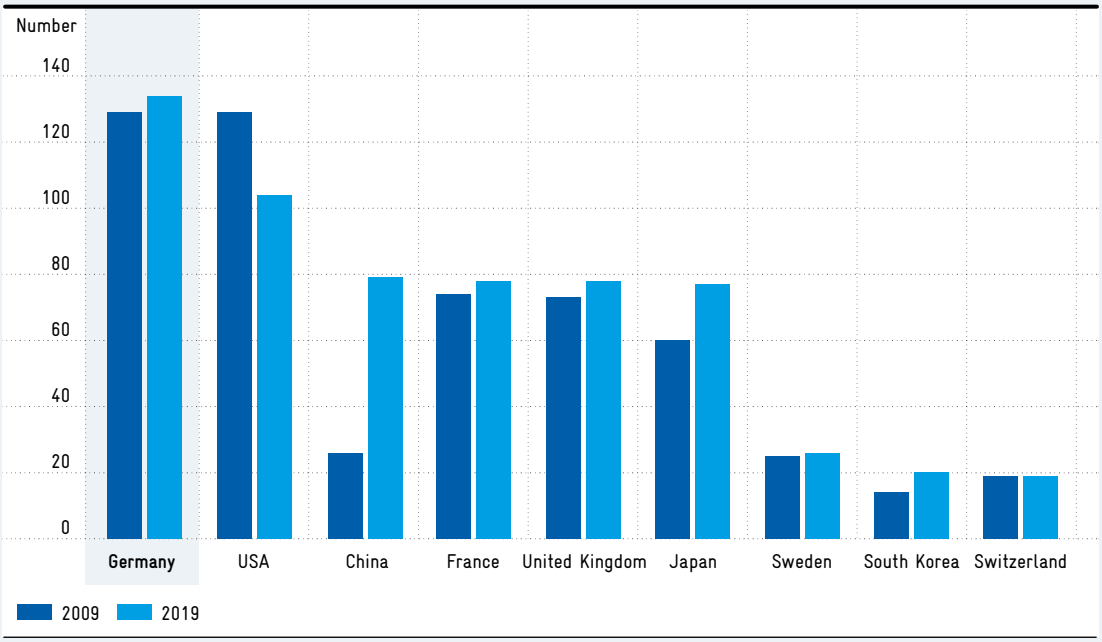


2006: break in time series.
Source: Mannheim Innovation Panel. Calculations by ZEW (ZEW – Leibniz Centre for European Economic Research).

Fig. C 3-4

Download data

Number of secretariats listed by the technical committees and subcommittees of the International Organization for Standardization (ISO)



Source: own diagram based on ISO (2010: 33) and https://www.iso.org/members.html (last accessed on 16 December 2019).

Financing research and innovation[330]

C 4

Public financing of research and development (R&D) in the business sector can take place via either direct R&D funding (project funding) or indirect R&D funding (in particular through tax incentives). Figure C 4-1 shows direct and indirect R&D funding as a percentage of gross domestic product (GDP) in selected countries. In the year under review (2016), the instrument of tax incentives for R&D activities was available to businesses in most of the countries listed; Germany, however, was not yet making use of this funding option in that year. The German Law on Tax Incentives for R&D (Forschungszulagengesetz) came into force at the beginning of 2020. As a result, the instrument of tax incentives for R&D activities is now also available in Germany.

Financing constitutes a major challenge for many innovative companies – not only in the start-up phase, but also during the growth phase.[331] Young, innovative enterprises can often only establish themselves successfully on the market if private investors provide venture capital during the start-up and growth phases.

Figure C 4-2 provides an overview of venture-capital investment as a percentage of national GDP in selected European countries. The data used for the comparison come from Invest Europe, formerly the European Private Equity and Venture Capital Association (EVCA); they offer good international comparability due to the harmonized collection and processing system used.[332] Germany only ranks about mid-table here in a European comparison. The highest levels of venture-capital investment relative to GDP in 2018 were recorded in Finland and Sweden. In Germany, venture-capital investment as a percentage of GDP rose only slightly in 2018 compared to the previous year.

Since the Invest Europe data only include venture-capital investment companies that are organized in the association, there is a risk of underestimating volumes.[333] Data from transactional databases[334] are therefore also used in addition to the Invest Europe data for the analysis of venture-capital investment in Germany. They have the advantage that the individual transaction is the observation unit; this increases the likelihood that co-investments by atypical market participants[335] and non-European investors are also included.

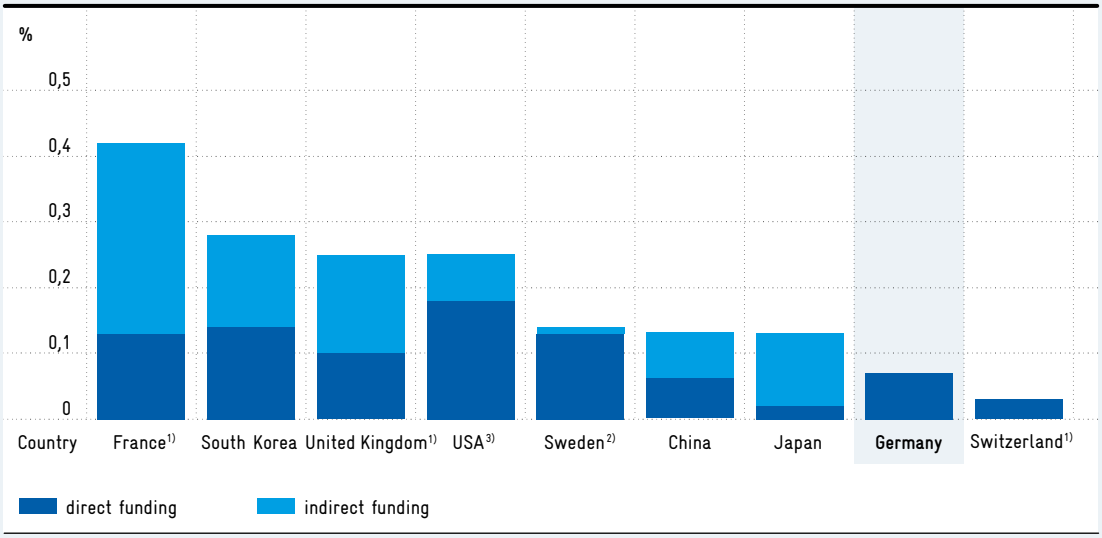
Figure C 4-3 provides an overview of the development of venture-capital investment in Germany. Invest Europe data show a slight increase in venture-capital investment in 2018 compared to the previous year due to an increase in early-stage venture-capital investments. A significant increase in transactional data can be observed in the period from 2009 to 2018. Using this data leads to a significant change in the structure of venture-capital investment. However, such a change would probably also be found for other countries. The extended data base does not, therefore, allow conclusions to be drawn on whether Germany's weak position by international comparison as regards the availability of venture capital might have improved in the meantime relative to other countries.

Fig. C 4-1

Download data

R&D expenditure in the business sector directly and indirectly funded by the public sector in 2016 as a percentage of national gross domestic product

The public funding of private-sector R&D is divided into direct R&D funding (project funding) and indirect R&D funding (through tax incentives).



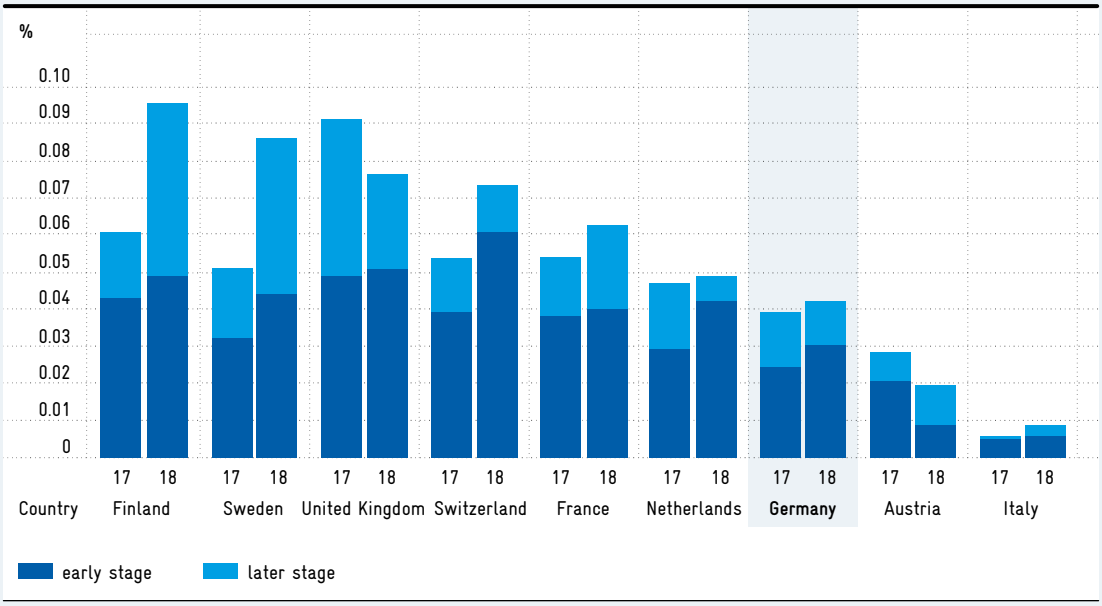
1) 2015. 2) 2014. 3) 2013.
Source: OECD R&D Tax Incentive Database, research December 2019.

Fig. C 4-2

Download data

Venture-capital investment as a percentage of national gross domestic product in 2017 and 2018

Venture capital is defined here as temporary equity investments in young, innovative, non-listed companies.



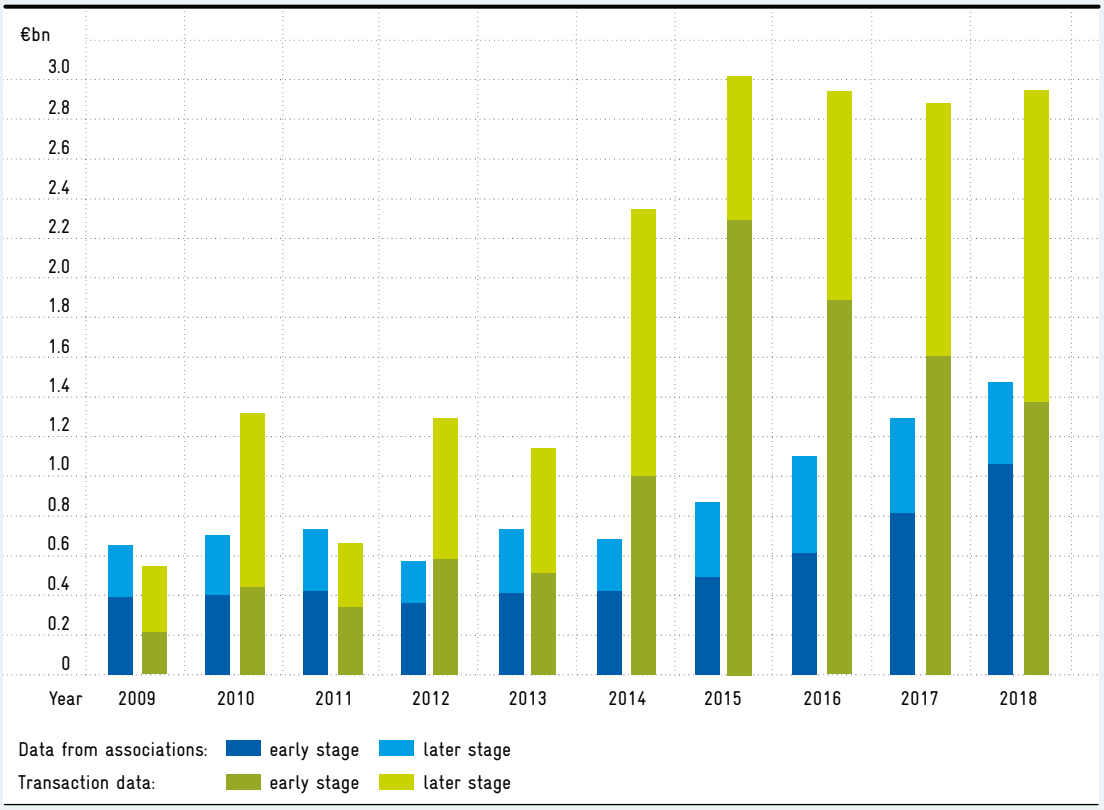
Data for 2017 partly revised.
Investments are broken down according to the portfolio companies' head offices. Early stage comprises the seed phase and the start-up phase.
Source: Invest Europe. Calculations by ZEW (ZEW – Leibniz Centre for European Economic Research) in Bersch et al. (2020).

Development of venture-capital investment in Germany 2009–2018 in €bn

Fig. C 4-3

Download data

Venture capital is defined here as temporary equity investments in young, innovative, non-listed companies.



Data revised.
Investments are broken down according to the portfolio companies' head offices. Early stage comprises the seed phase and the start-up phase.
Source of association data: Invest Europe. Calculations by ZEW (ZEW – Leibniz Centre for European Economic Research) in Bersch et al. (2020).
Source of transaction data: Bureau van Dijk, Majunke. Calculations by ZEW (Centre for European Economic Research) in Bersch et al. (2020).

C 5 New businesses

An international comparison of start-up rates, i.e. the number of new businesses as a percentage of the total number of companies, is only possible at the European level.[336] The Business Demography Statistics provided by Eurostat are used here for this purpose (C 5-1). They constitute part of the European Union's Structural Business Statistics (SBS), an official database that is based on evaluations of business registers in the individual Member States. The figures for Germany are provided by the Federal Statistical Office's business demography statistics, which are derived from the German business register.[337] In 2017, the start-up rate in Germany was 6.8 percent, well below the figures for the UK (13.5 percent), France (10 percent) and the Netherlands (9.5 percent).[338] Germany's start-up rate of 3.4 percent in the R&D-intensive industries was the lowest of the countries examined here. Germany also failed to reach a top position in knowledge-intensive services, where its start-up rate was 8 percent.

The figures on business dynamics in the knowledge-intensive sectors shown in charts C 5-2 to C 5-4 are taken from an evaluation of the Mannheim Enterprise Panel (MUP) conducted by the ZEW – Leibniz Centre for European Economic Research (ZEW). The MUP is a ZEW panel dataset on businesses located in Germany. It is compiled in cooperation with Creditreform, the largest credit information bureau in Germany.[339] The definition of 'business' used by the MUP is restricted exclusively to economically active companies; 'start-ups' are defined as original, newly formed businesses.[340] The start-up rate shown in figure C 5-2 is thus calculated on the basis of different data from those used in the Business Demography Statistics, so that a direct comparison cannot be drawn here.[341] This means that the figures deviate from those given in Figure C 5-1 for Germany. After the start-up rate in the knowledge-intensive sectors fell significantly in the years following the financial and economic crisis, it has remained relatively constant in recent years. In 2018, it amounted to 4.3 percent – the same as in the two previous years.[342]

It is gratifying that the closure rate, i.e. market exits, in the knowledge- intensive sectors has fallen for the last four years in a row and was only 2.7 percent in 2018 (C 5-3).[343] In all the sectors of the knowledge-intensive sectors examined, the current rate was lower than at any time during the period under review.

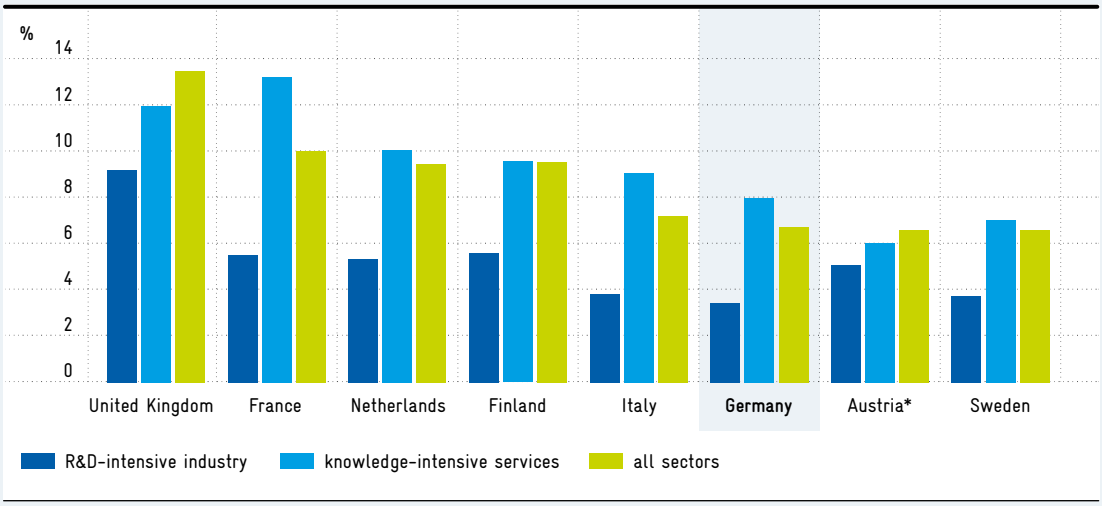
A comparison of the Länder for the period 2016 to 2018 shows that the start-up rates across all sectors were lower in the east German territorial Länder than in west German territorial Länder and in city states (C 5-4).[344] However, looking at R&D-intensive industry, Saxony-Anhalt and Brandenburg had start-up rates (4.2 and 3.6 percent) that were surpassed only by Berlin and Hamburg. Berlin and Hamburg had the highest start-up rates of all Länder: across all industries (6.8 and 5.4 percent), in R&D-intensive industries (4.7 and 4.1 percent), and in knowledge-intensive services (6.8 and 4.7 percent).

Start-up rates in 2017 by international comparison as percentages

Fig. C 5-1

Download data

Start-up rate: number of start-up businesses as a percentage of the total number of companies.



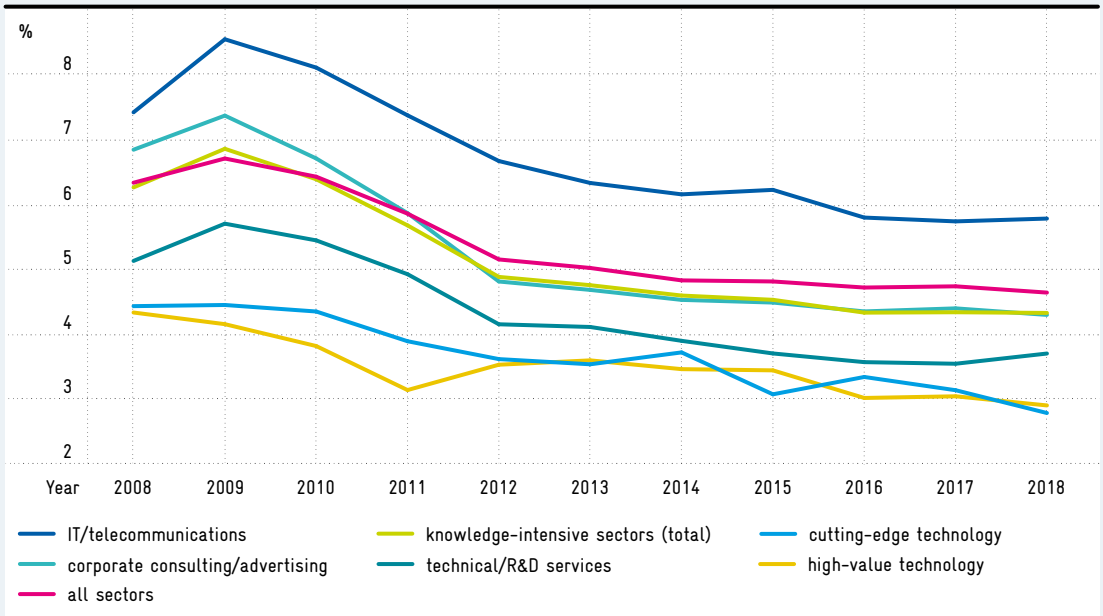
* 2016.
Source: Business Demography Statistics (Eurostat). Calculations by ZEW (ZEW – Leibniz Centre for European Economic Research) in Bersch et al. (2020).

Start-up rates in Germany's knowledge-intensive sectors 2008-2018 as percentages

Fig. C 5-2

Download data

Start-up rate: number of start-up businesses as a percentage of all companies.



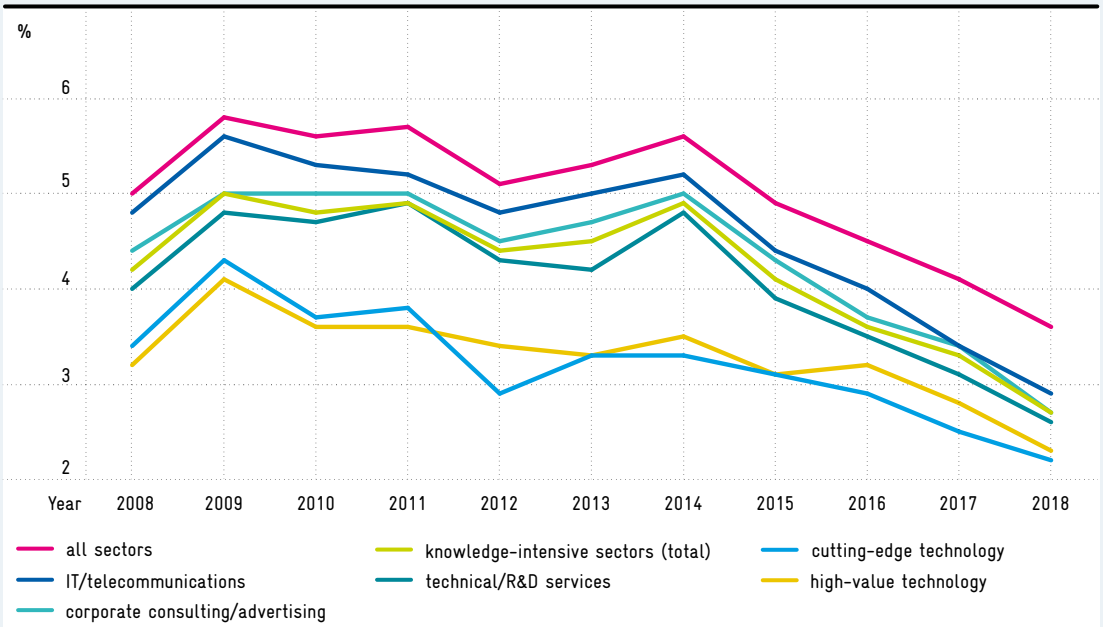
All figures are provisional.
Source: Mannheim Enterprise Panel. Calculations by ZEW (ZEW – Leibniz Centre for European Economic Research) in Bersch et al. (2020).

Fig. C 5-3

Download data

Closure rates in Germany's knowledge-intensive sectors 2008–2018 as percentages

Closure rate: number of companies that close down during a year as a percentage of all companies.



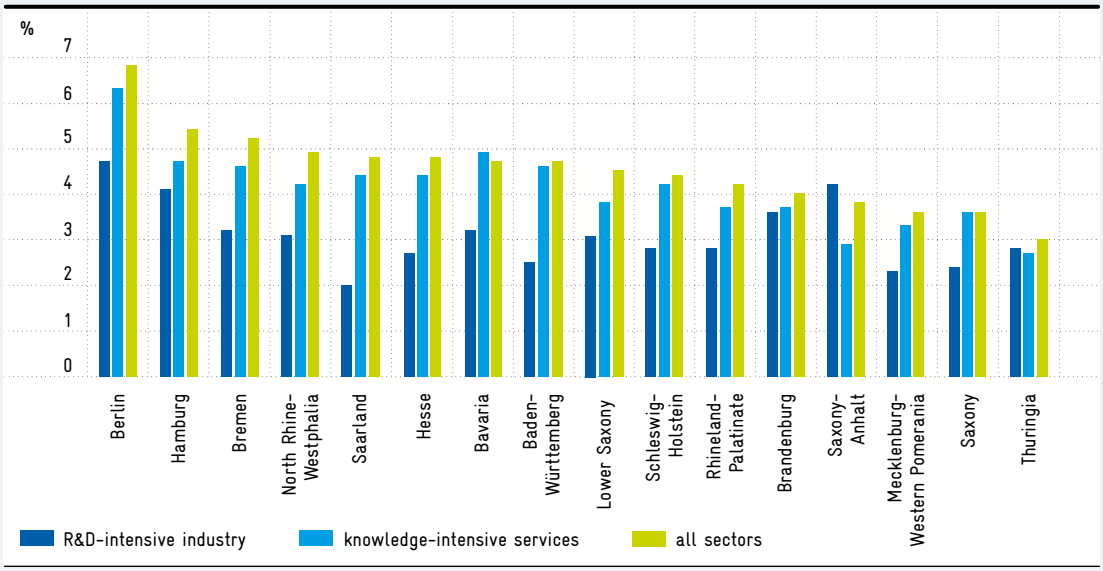
All figures are provisional.
Source: Mannheim Enterprise Panel. Calculations by ZEW (ZEW – Leibniz Centre for European Economic Research) in Bersch et al. (2020)

Fig. C 5-4

Download data

Start-up rates by Länder 2016–2018 as percentages

Start-up rate: number of start-up businesses as a percentage of all companies.



All figures are provisional.
Source: Mannheim Enterprise Panel. Calculations by ZEW (ZEW – Leibniz Centre for European Economic Research) in Bersch et al. (2020)

Patents[345]

C 6

Since the mid-2000s, transnational patent applications have been stagnating both in Germany and in other major European economies like the UK, Sweden and Switzerland (C 6-1). By contrast, particularly China, Japan and South Korea have recorded high growth rates. China has overtaken Germany in the meantime and is now one of the leading nations in transnational patent applications together with Germany, the USA and Japan.

While the USA was in the lead in terms of the absolute number of applications in 2017, it was not among the frontrunners when it came to patent intensity (i.e. patent applications per million of the working population) (C 6-2). Here, the leaders were Switzerland, Sweden and Japan, followed by Finland, Germany and South Korea. Patents are an important tool for securing market shares in the context of the international technology trade. A high patent intensity therefore reflects both a strong international orientation and a pronounced export focus on the part of the respective economy.

Further conclusions on a country's technological performance can be drawn from patent activities in the field of R&D-intensive technology. This sector is made up of industries that invest more than three percent of their turnover in R&D (R&D intensity). R&D-intensive technology comprises the areas of high-value technology (R&D intensity between three and nine percent) and cutting-edge technology (R&D intensity over nine percent).

International comparisons show that Germany is highly specialized in high-value technology (C 6-3) as a result of its traditional strengths in the automotive, mechanical-engineering and chemical industries. Germany has the highest specialization rate in high-value technology in the reference group.

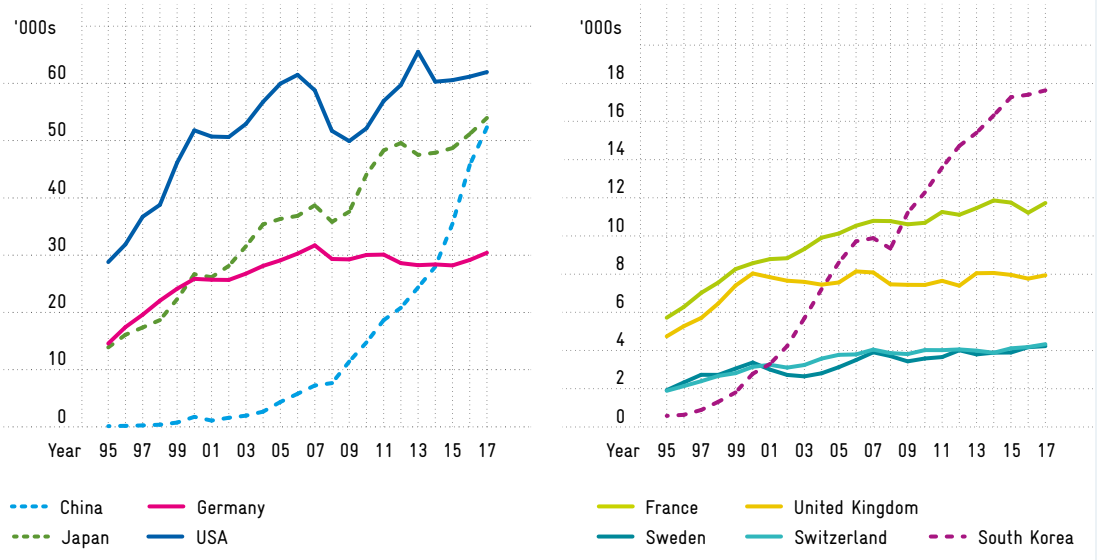
By contrast, China, Sweden, South Korea and the USA are more specialized in cutting-edge technology (C 6-4).

Fig. C 6-1

Download data

Development of the number of transnational patent applications in selected countries 1995–2017

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 one application filed with the European Patent Office.



Source: EPO (PATSTAT). Calculations by Fraunhofer ISI in Neuhäusler et al. (2020)

Tab. C 6-2

Download data

Absolute number, intensity and growth rates of transnational patent applications in the field of R&D-intensive technology in 2017[1)]

The R&D-intensive technology sector comprises industries that invest more than three percent of their turnover in research and development. Intensity is calculated as the number of patents per million gainfully employed persons.

	absolute [1)]	intensities [1)]	intensities in R&D-intensive technology	growth (2007 = 100) [1)]	growth in R&D-intensive technology (2007 = 100)
Total	**289,834**	–	–	**136**	**135**
China	52,320	69	47	723	689
Germany	**30,409**	**730**	**423**	**96**	**98**
EU-28	79,355	349	199	103	103
Finland	1,962	793	454	101	87
France	11,729	436	255	109	107
United Kingdom	7,942	248	147	98	100
Italy	5,735	249	118	92	90
Japan	53,949	826	494	139	128
Canada	3,374	183	112	85	79
Netherlands	4,903	570	310	114	113
Sweden	4,231	843	594	108	119
Switzerland	4,331	934	480	107	100
South Korea	17,627	660	413	178	161
USA	61,960	404	264	105	104

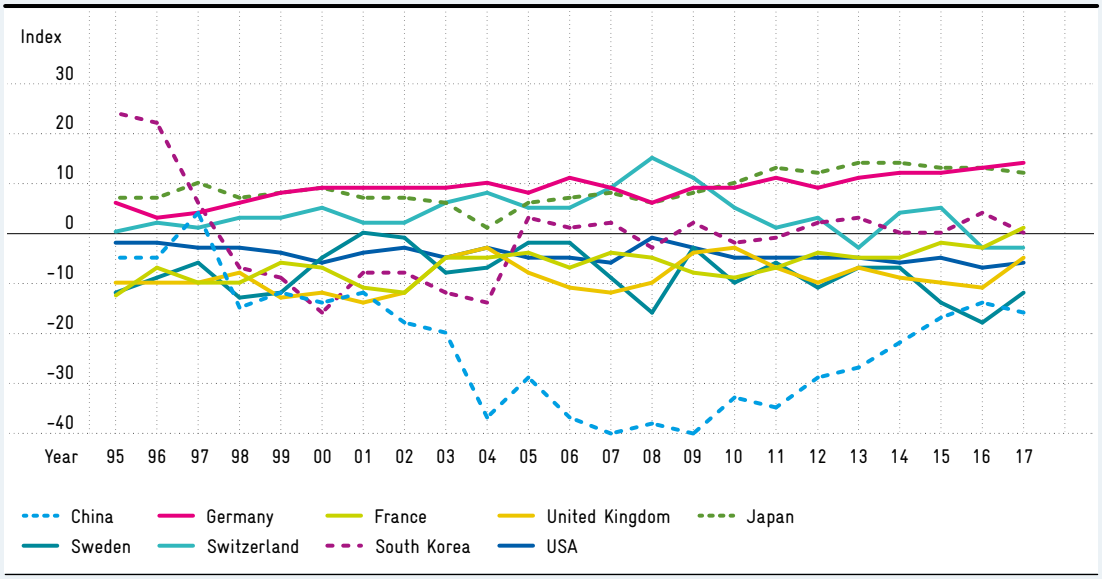
[1)] Figures refer to all industries.
Source: EPO (PATSTAT), OECD (MSTI), World Bank. Calculations by Fraunhofer ISI in Neuhäusler et al. (2020)

Development of the specialization index in selected countries over time in the field of high-value technology 1995–2017

Fig. C 6-3

Download data

The specialization index is calculated on the basis of all transnational patent applications worldwide. Positive or negative values indicate whether the surveyed country's level of activity in a given field is disproportionately high or disproportionately low compared to the global average.



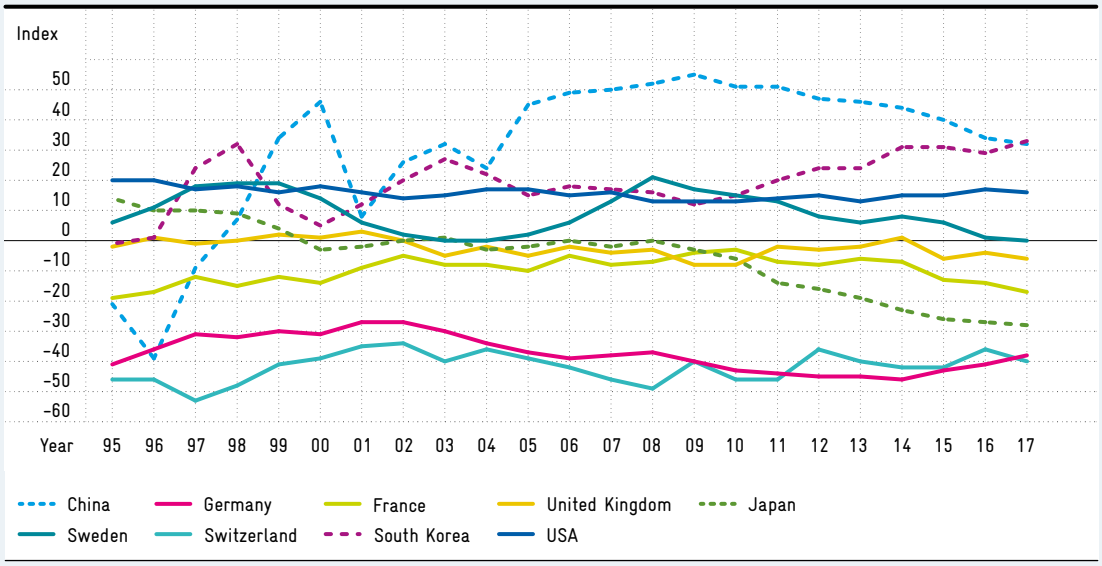
Source: EPO (PATSTAT), OECD (MSTI), World Bank. Calculations by Fraunhofer ISI in Neuhäusler et al. (2020)

Development of the specialization index in selected countries over time in the field of cutting-edge technology 1995–2017

Fig. C 6-4

Download data

The specialization index is calculated on the basis of all transnational patent applications worldwide. Positive or negative values indicate whether the surveyed country's level of activity in a given field is disproportionately high or disproportionately low compared to the global average.



Source: EPO (PATSTAT), OECD (MSTI), World Bank. Calculations by Fraunhofer ISI in Neuhäusler et al. (2020)

C 7 Scientific publications[346]

A large proportion of new technologies and services are based on developments and results from science. Bibliometric indicators and metrics are regularly used as yardsticks for evaluating scientific achievements to estimate the performance of a research and science system in both quantitative and qualitative terms.

The bibliometric database Web of Science covers worldwide publications in scientific journals, as well as citations from these publications. The research affiliation of scientists referenced in the database makes it possible to assign individual publications to a specific country. Fractional counting is employed in cases where several co-authors from different countries contribute to a publication. Indicators on the quantity and quality of scientific publications can be used to assess the performance of a research and science system.

Significant changes can be identified in selected countries' and regions' shares of all publications in Web of Science (C 7-1) by comparing the years 2008 and 2018. Most countries' publication shares have declined, including the major western European nations of Germany, France and the United Kingdom, as well as the USA. Germany's share of publications fell from 5.4 to 4.3 percent, the UK's from 5.6 to 4.5 percent, France's from 3.9 to 2.7 percent and the USA's from 24.4 to 18.6 percent. By contrast, China's share of publications grew enormously from 8.4 to 20.4 percent. Denmark was the only European country to increase its share of publications: between 2008 and 2018 its share rose from 0.6 to 0.7 percent.

The international alignment (IA) of publications in Web of Science from selected countries and regions (C 7-2) is an indicator of the quality of scientific publications. Germany's index value rose from 13 to 16 between 2008 and 2016. The quality of publications by authors from Germany has thus improved. According to this indicator, publications from Switzerland, the USA and the Netherlands are of the highest quality. China has been able to improve its publication quality considerably and for the first time achieved an above-average value for 2016 with an index value of 3.

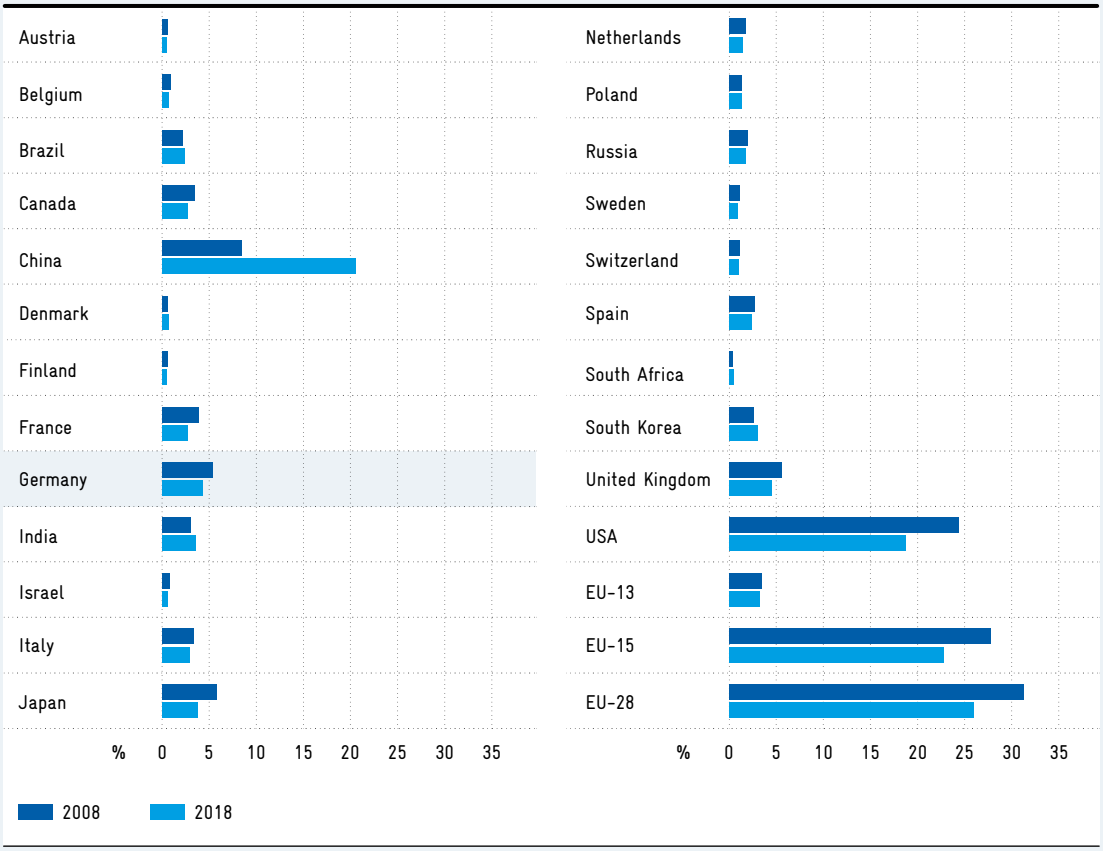
The scientific regard (SR) of specific countries and regions for publications in Web of Science (C7-3) shows that the index value for articles written in Germany fell from 9 to 3 between 2008 and 2016. In 2016 compared to 2008, articles from Germany were thus cited less frequently than other articles in the journals in which they were published.

Percentages of all publications in Web of Science from selected countries and regions in 2008 and 2018

Fig. C 7-1

Download data

The analysis concentrates on countries' shares, rather than on absolute figures, to compensate for changes, especially the ongoing expansion of data collection.



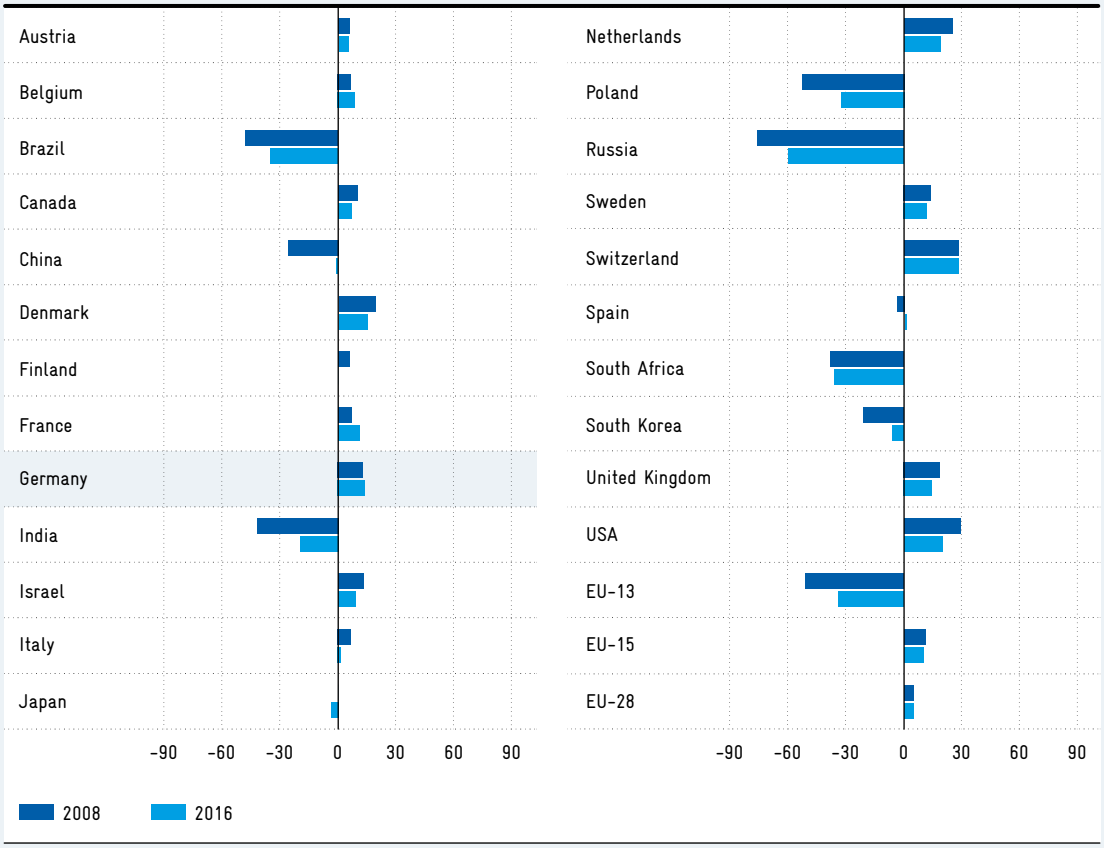
Fractional counting.
Source: Web of Science. Research and calculations by DZHW in Stephen et al. (2020).

Fig. C 7-2

Download data

International alignment (IA) of publications in Web of Science from selected countries and regions in 2008 and 2016 (index values)

The IA index indicates whether a country's authors publish in internationally more highly recognized or less highly recognized journals relative to the world average. Positive or negative values indicate an above-average or below-average IA.



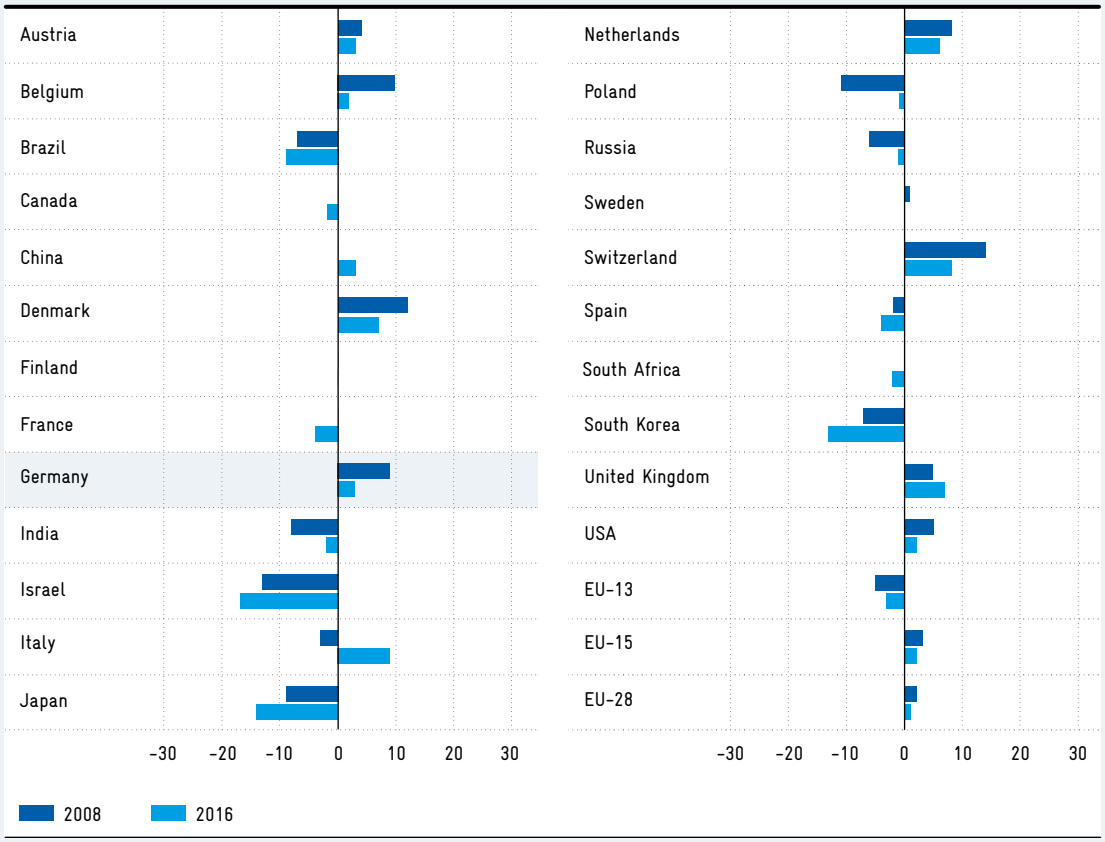
Fractional counting.
Source: Web of Science. Research and calculations by DZHW in Stephen et al. (2020).

Scientific regard (SR) of publications in Web of Science from selected countries and regions in 2008 and 2016 (index values)

Fig. C 7-3

Download data

The SR index indicates whether a country's articles are cited on average more frequently or more seldom than other articles in the journals in which they appeared. Positive or negative values indicate an above-average or below-average scientific regard. The index is calculated without self-citations.



Fractional counting.
Source: Web of Science. Research and calculations by DZHW in Stephen et al. (2020).

C 8 Production, value added and employment[347]

A country's specialization pattern in foreign trade can be measured using the RCA indicator,[348] which shows a product group's export/import ratio relative to the export/import ratio of processed industrial goods overall. As in previous years, Germany again showed a comparative advantage in trade in R&D-intensive goods in 2018 (C 8-1). R&D-intensive goods are made up of high-value technology goods and cutting-edge technology goods. A more precise analysis of these two groups of goods shows that Germany had a positive comparative advantage only in trade with high-value technology goods; in trade with cutting-edge technology goods, however, it had a negative comparative advantage, albeit with a slightly positive trend. France, the UK, Switzerland, South Korea and the USA had positive RCA indicators figures for cutting-edge technology; China and Japan had a negative RCA indicator here for the whole period under review. Sweden has recorded negative figures since 2010.

The contribution of research-intensive and knowledge-intensive industries to a country's value added allows conclusions to be drawn about its technological performance by international comparison (C 8-2). Relative to the other countries studied, Germany's share of value added was highest in the field of high-value technology, amounting to 9.3 percent in 2017. In the field of cutting-edge technology, Germany's figure of 3.0 percent was much lower than the frontrunners Switzerland (8.8 percent) and South Korea (7.8 percent). In all the countries examined, knowledge-intensive services contributed much more to national value added than research-intensive industries. However, with a value-added share of 24.4 percent they played a more minor role in 2017 in Germany than in the other countries under consideration (exception: South Korea).

Following the decline in gross value added in several industrial sectors in the crisis year of 2009, value added in Germany has continuously increased since 2010 (C 8-3). At 3.3 percent, growth in knowledge-intensive services was higher in 2017 than in the previous year (2.3 percent). A greater increase in value added was also recorded in non-knowledge-intensive services (4.2 percent compared to 3.0 percent). In manufacturing, on the other hand, the increase in value added was higher in 2016 than in 2017. In 2017, it was 4.3 percent in knowledge-intensive manufacturing (2016: 6.0 percent), and 2.2 percent in non-knowledge-intensive manufacturing (2016: 4.1 percent).

The services sector was the main source of the increase in employment subject to social insurance contributions in various industrial sectors of the German economy between 2011 and 2018 (C 8-4). Employment rose by 15.4 percent in non-knowledge-intensive services and by 19.8 percent in knowledge-intensive services during this period. Employment subject to social insurance contributions rose by 7.5 percent in non-knowledge-intensive manufacturing and by 10.7 percent in knowledge-intensive manufacturing.

Revealed comparative advantage (RCA) of selected countries in foreign trade in research-intensive goods 2005–2018

Tab. C 8-1

Download data

Year	China [1]	France	Germany	Japan	Sweden	Switzerland	South Korea	United Kingdom	USA
				R&D-intensive goods					
2005	-29	7	10	42	-1	18	17	14	17
2010	-27	6	12	33	-6	22	19	11	1
2015	-27	5	13	31	-5	28	13	3	2
2018	-29	5	12	30	-3	29	16	8	-2
				high-value technology goods					
2005	0	6	27	75	-1	18	17	4	-5
2010	-16	-2	30	61	-6	22	19	15	-10
2015	-3	-6	27	63	-5	28	13	1	-14
2018	-2	-9	23	64	-3	29	16	5	-18
				cutting-edge technology goods					
2005	-53	8	-34	-14	1	4	24	33	55
2010	-35	20	-35	-22	-11	25	33	1	22
2015	-46	21	-23	-35	-22	41	12	8	27
2018	-51	29	-17	-44	-35	29	30	13	23

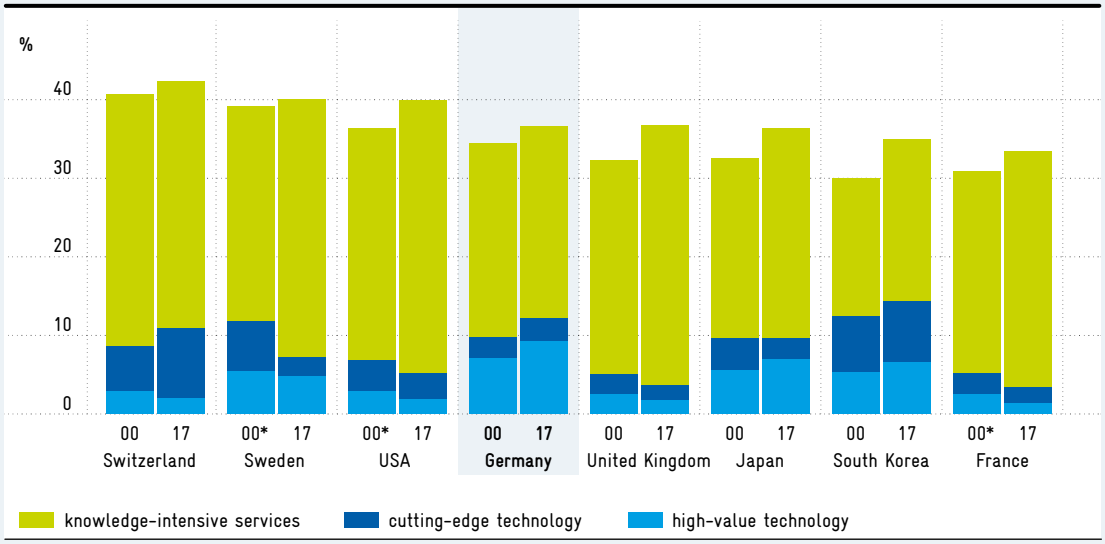
A positive RCA value means that the exp./imp. ratio for this product group is higher than for manufactured industrial goods as a whole.
[1] Incl. Hong Kong.
Source: UN COMTRADE database, research November 2019. Calculations and estimates by CWS in Gehrke and Schiersch (2020).

R&D-intensive industries and knowledge-intensive services as a percentage of value added in 2000 and 2017

Fig. C 8-2

Download data

R&D-intensive industries have an above-average R&D intensity, while knowledge-intensive services are characterized by an above-average proportion of employees with tertiary education qualifications.



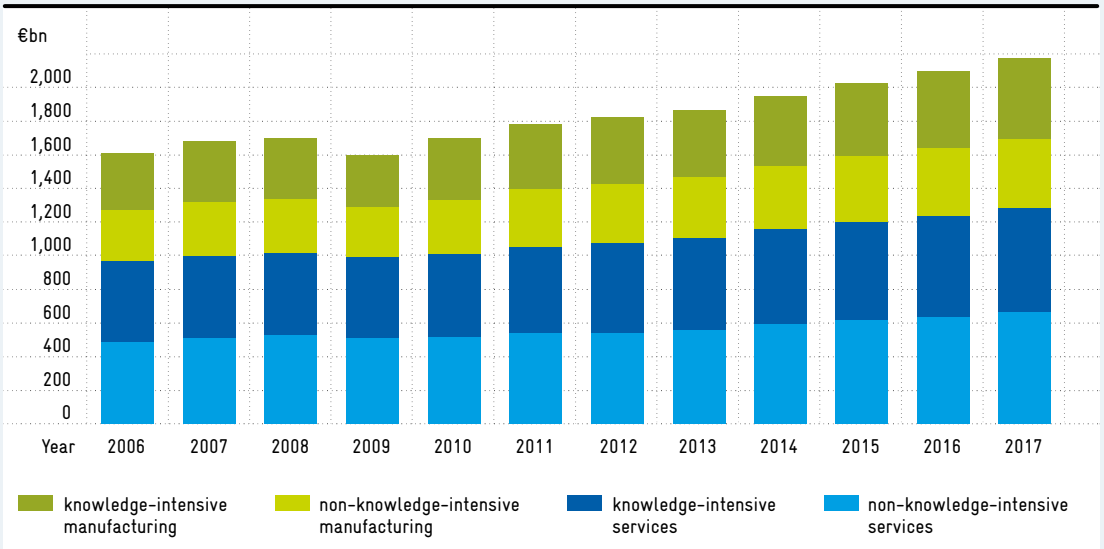
* Data partly revised.
Source: OECD-NA, OECD-STAN, OECD-SBS, Eurostat-NA, Eurostat-SBS, EU KLEMS. Calculations and estimates by DIW Berlin in Gehrke and Schiersch (2020).

Fig. C 8-3

Download data

Development of gross value added in different industrial sectors of the economy in Germany 2006–2017 in €bn

Gross value added is the difference between the total value of all goods and services produced and the intermediate inputs received from other companies for their production.



Not including agriculture, forestry, fisheries, public administration and services, real estate and housing, education, private households, social insurance, religious and other organizations, associations and trade unions.
Data slightly revised due to a fundamental revision of the national accounts in 2019.
Source: Statistisches Bundesamt (Federal Statistical Office), Fachserie 18, Reihe 1.4. Calculations by CWS in Gehrke and Schiersch (2020).

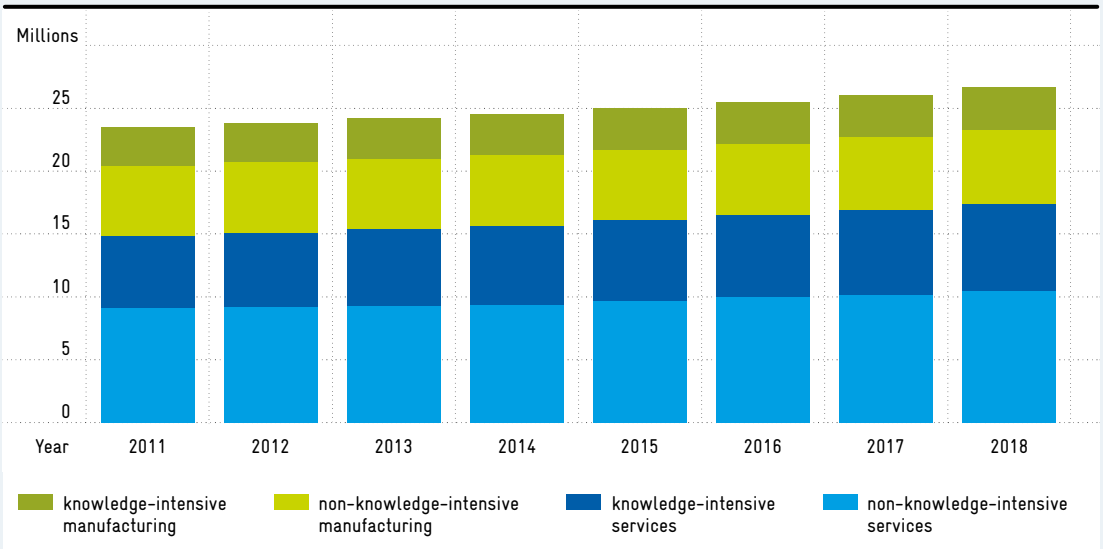
C

Fig. C 8-4

Download data

Development of the number of employees subject to social insurance contributions in different industrial sectors of the economy in Germany 2011–2018 in millions

Employees covered by social security insurance comprise all employees who are liable to contribute to health, pension and long-term care insurance, and/or to pay contributions according to German employment-promotion law, or for whom contribution shares must be paid to statutory pension insurance or according to German employment-promotion law.



Source: Federal Employment Agency. Calculations by CWS in Gehrke and Schiersch (2020).

LISTS

Contents

List of figures, tables and boxes

D 1

D 2 List of abbreviations

Abs.	paragraph (Absatz)
AFO	Contract and Development Research East (Auftrags- und Entwicklungsforschung Ost)
AI	artificial intelligence
APRA	Asia-Pacific Research Area
APT	Advanced Persistent Threat
Art.	Article (Artikel)
AUF	non-university research institution (außeruniversitäre Forschungseinrichtung)
AV-DFG	Implementation Agreement on the GWK Agreement on Joint Funding by the German Research Foundation (Ausführungsvereinbarung zum GWK-Abkommen über die gemeinsame Förderung der Deutschen Forschungsgemeinschaft)
AWO	Contract Research West-East (Auftragsforschung West-Ost)
BA	Federal Employment Agency (Bundesagentur für Arbeit)
BAFA	Federal Office of Economics and Export Control (Bundesagentur für Wirtschaft und Ausfuhrkontrolle)
BBDC	Berlin Big Data Centre
BBSR	Federal Institute for Research on Building, Urban Affairs and Spatial Development (Bundesinstitut für Bau-, Stadt- und Raumforschung)
BDI	Federation of German Industries (Bundesverband der Deutschen Industrie e.V.)
BIFOLD	Berlin Institute for the Foundations of Learning and Data
Bitkom	Federal Association for Information Technology, Telecommunications and New Media (Bundesverband Informationswirtschaft, Telekommunikation und neue Medien e.V.)
BMAS	Federal Ministry of Labour and Social Affairs (Bundesministerium für Arbeit und Soziales)
BMBF	Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung)
BMEL	Federal Ministry of Food and Agriculture (Bundesministerium für Ernährung und Landwirtschaft)
BMF	Federal Ministry of Finance (Bundesministerium der Finanzen)
BMFSFJ	Federal Ministry for Family Affairs, Senior Citizens, Women and Youth (Bundesministerium für Familie, Senioren, Frauen und Jugend)
BMG	Federal Ministry for Health (Bundesministerium für Gesundheit)
BMI	Federal Ministry of the Interior, Building and Community (Bundesministerium des Innern, für Bau und Heimat)
BMJV	Federal Ministry of Justice and Consumer Protection (Bundesministerium für Justiz und Verbraucherschutz)
BMU	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (Bundesministerium für Umwelt, Natur und nukleare Sicherheit)
BMVg	Federal Ministry of Defence (Bundesministerium der Verteidigung)
BMVI	Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur)
BMWi	Federal Ministry for Economics and Energy (Bundesministerium für Wirtschaft und Energie)

BSI	Federal Office for Information Security (Bundesamt für Sicherheit in der Informationstechnik)
BZML	Berlin Centre for Machine Learning (Berliner Zentrum für Maschinelles Lernen)
CAS	Chinese Academy of Sciences
CERT	Computer Emergency Response Team
CHIKOH	Expertise on China in Hohenheim
CIS	Community Innovation Survey
CISPA	Helmholtz Center for Information Security
CO_2	carbon dioxide
CPS	cyber-physical systems
CRISP	Centre for Research in Security and Privacy
CWS	Centre for Economic Policy Studies (Center für Wirtschaftspolitische Studien)
Cyber-AZ	National Cyber Defence Centre (Nationales Cyber-Abwehrzentrum)
DCPI	Sino-German Innovation Platform (Deutsch-Chinesische Plattform Innovation)
DDoS	distributed denial of service
DFG	German Research Foundation (Deutsche Forschungsgemeinschaft e.V.)
DFKI	German Research Centre for Artificial Intelligence (Deutsches Forschungszentrum für Künstliche Intelligenz GmbH)
DIW	German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung e.V.)
DZHW-ICE	German Centre for Research on Higher Education and Science Studies – Information, Controlling, Decision (Deutsches Zentrum für Hochschul- und Wissenschaftsforschung GmbH – Information, Controlling, Entscheidung)
EDC	European Data Cooperative
EFI	Commission of Experts for Research and Innovation (Expertenkommission Forschung und Innovation)
EPO	European Patent Office
ERP	enterprise resource planning
EU ETS	European Union Emissions Trading System
EU	European Union
EUROSTAT	Statistical Office of the European Commission
EVCA	European Private Equity and Venture Capital Association
EXIST	EXIST – University-Based Business Start-Ups (Existenzgründungen aus der Wirtschaft)
FDI	foreign direct investment
FOKO	research cooperation in small and medium-sized businesses (Forschungskooperation in der mittelständischen Wirtschaft)
ForMaT	Team Research for the Market (Forschung für den Markt im Team)
FUEGO	R&D Community Project East (FuE-Gemeinschaftsvorhaben-Ost)
FZI	Research Centre for Information Technology (Forschungszentrum Informatik)
GDP	gross domestic product
GERD	Gross Domestic Expenditure on Research and Development
GG	Basic Law (Grundgesetz)
GRW	Joint Task for the Improvement of Regional Economic Structures (Gemeinschaftsaufgabe Verbesserung der regionalen Wirtschaftsstruktur)
GWK	Joint Science Conference (Gemeinsame Wissenschaftskonferenz)
HTS	High-Tech Strategy
IA	international alignment
IAB	Institute for Employment Research of the Federal Employment Agency (Institut für Arbeitsmarkt- und Berufsforschung der Bundesagentur für Arbeit)
ICT	information and communication technology
IFP	innovation support programme (Innovationsförderprogramm)
IGD	(Fraunhofer) Institute for Computer Graphics Research (Institut für Graphische Datenverarbeitung)
IGP	innovation programme for business models and pioneer solutions (Innovationsprogramm für Geschäftsmodelle und Pionierlösungen)

IHK	Chamber of Industry and Commerce (Industrie- und Handelskammer)
IKT	Information and Communication Technology (Informations- und Kommunikationstechnik bzw. -technologie)
IMW	(Fraunhofer) Centre for International Management and Knowledge Economics (Internationales Management und Wissensökonomie)
INNO-KOM	R&D support for non-profit external industrial research institutions – Innovation Competence (FuE-Förderung gemeinnütziger externer Industrieforschungseinrichtungen – Innovationskompetenz)
InnoMan	external innovation management for small enterprises in the new Länder (Externes Innovationsmanagement für Kleinunternehmen in den neuen Bundesländern)
Inno-Net	promotion of innovative networks (Förderung von innovativen Netzwerken)
InnoProfile	promotion of business-oriented junior research groups in the new Länder (Förderung von wirtschaftsorientierten Nachwuchsforschungsgruppen in den neuen Ländern)
InnoRegio	promotion of the formation of regional innovation networks and their innovation projects in the new Länder (Förderung der Bildung regionaler Innovationsnetzwerke und deren Innovationsvorhaben in den neuen Ländern)
INNO-Watt	innovative growth drivers (Innovative Wachstumsträger)
IOSB	(Fraunhofer) Institute for Optronics, System Technologies and Image Exploitation (Institut für Optronik, Systemtechnik und Bildauswertung)
IoT	Internet of Things
ISCED	International Standard Classification of Education
ISI	(Fraunhofer) Institute for Systems and Innovation Research
ISO	International Organization for Standardization
IT	information technology
IWH	Leibniz Institute for Economic Research, Halle (Leibniz-Institut für Wirtschaftsforschung Halle)
KASTEL	Competence Centre for Applied Security Technology (Kompetenzzentrum für angewandte Sicherheitstechnologie)
KIT	Karlsruhe Institute of Technology
KLEMS	Capital, Labour, Energy, Materials and Service
KRITIS	Critical Infrastructure Protection (Schutz Kritischer Infrastrukturen)
M&A	mergers & acquisitions
MCML	Munich Centre for Machine Learning
MIP	Mannheim Innovation Panel (Mannheimer Innovationspanel)
ML2R	Competence Centre Machine Learning Rhine-Ruhr
MOFCOM	Ministry of Commerce
MPI-INF	Max Planck Institute for Computer Science (Max-Planck-Institut für Informatik)
MPI-SWS	Max Planck Institute for Software Systems
MSTI	Main Science and Technology Indicators
MUP	Mannheim Enterprise Panel (Mannheimer Unternehmenspanel)
MVI	industrial research to prepare the market (Marktvorbereitende Industrieforschung)
NA	national accounts
NAFTA	North American Free Trade Agreement
NDRC	National Development and Reform Commission
NEMO	Network Management East (Netzwerkmanagement Ost)
NESTI	National Experts on Science and Technology Indicators
NGO	non-governmental organization
NIS	Network and Information Security
OECD	Organization for Economic Cooperation and Development
PATSTAT	Patent Statistical Database
PCT	Patent Cooperation Treaty
PFI	Pact for Research and Innovation (Pakt für Forschung und Innovation)
PFO	R&D Personnel Funding East (FuE-Personalförderung Ost)

PRO INNO	programme to promote the innovative competence of SMEs (Programm zur Förderung der Erhöhung der Innovationskompetenz mittelständischer Unternehmen)
PtJ	Project Management Jülich (Projektträger Jülich)
R&D	research and development
R&I	research and innovation
RCA	revealed comparative advantage
ROR	spatial planning region (Raumordnungsregion)
RUBIN	regional entrepreneurial alliances for innovation (Regionale unternehmerische Bündnisse für Innovation)
SBS	Structural Business Statistics
ScaDS	Competence Center for Scalable Data Services and Solutions
SIT	(Fraunhofer Institute for) Secure Information Technology
SMEs	small and medium-sized enterprises
SoBEZ	federal supplementary grants to meet special needs (Sonderbedarfs-Bundesergänzungszuweisungen)
SprinD	Federal Agency for Disruptive Innovation (Bundesagentur für Sprunginnovationen)
STAN	Structural Analysis Database
STEM	Science, Technology, Engineering and Mathematics
SUS	Structural Business Statistics (Strukturelle Unternehmensstatistik)
SV	Stifterverband für die Deutsche Wissenschaft e.V.
SR	scientific regard
UNESCO	United Nations Educational, Scientific and Cultural Organization
WIPO	World Intellectual Property Organization
WIR!	Change through Innovation in the Region (Wandel durch Innovation in der Region)
WoS	Web of Science
WTO	World Trade Organisation
ZB	Zeitschriftenspezifische Beachtung
ZEW	Leibniz Centre for European Economic Research Mannheim (ZEW) Leibniz-Zentrum für Europäische Wirtschaftsforschung GmbH Mannheim (ZEW)
ZFO	R&D Personnel Growth Promotion East (FuE-Personalzuwachsförderung Ost)
ZIK	Centres for Innovation Competence (Zentren für Innovationskompetenz)
ZIM	Central Innovation Programme for SMEs (Zentrales Innovationsprogramm Mittelstand)
ZITiS	Central Office for Information Technology in the Security Sector (Zentrale Stelle für Informationstechnik im Sicherheitsbereich)

D 3 Glossary

Bildungsinländer and Bildungsausländer (foreign students)
New students with foreign nationality who gained their university entrance qualifications in Germany are known in Germany as 'Bildungsinländer' (lit. domestically educated persons) new students who gained their university entrance qualifications outside of Germany and come to Germany to study are known as 'Bildungsausländer' (lit. foreign-educated persons).

Breakthrough innovations
Breakthrough innovations are innovations that bring about far-reaching changes in markets, organizations and societies and open up great value-creation potential.

Closure rate
The closure rate is defined as the number of closed-down companies as a percentage of the annual average number of active companies in a country.

Clusters
Economic clusters are agglomerations and cooperation networks of economic and scientific actors in R&D and production that are usually located geographically close to each other and work in related fields.

Community Innovation Surveys
The Community Innovation Surveys (CIS) are innovation surveys that have been conducted regularly in the European Union since 1993 according to a uniform methodological standard.

Contract for the Future Strengthening of Higher Education and Teaching
The 'Contract for the Future Strengthening of Higher Education and Teaching' is an agreement between the Federal Government and the Länder aimed at ensuring a high quality of higher education and teaching throughout Germany, good study conditions across the whole German tertiary education landscape, and the maintenance of teaching capacity in line with demand. It was concluded for an unlimited period of time on the basis of Article 91b (1) of the Basic Law. From 2021 onwards, the Contract for the Future replaces the Higher Education Pact 2025 (cf. separate entry).

Corporation Tax Act
The Corporation Tax Act is the law governing the income taxation of legal entities; it includes, among other things, tax liability, the determination of income and the tax rate. Legal persons in this context are associations of persons who have legal capacity by law and are themselves bearers of rights and obligations, but not natural persons.

Cutting-edge technology
Cutting-edge technology goods refer to R&D-intensive goods (cf. separate entry) in the production of which, on an annual average, more than 9 percent of turnover is invested in research and development.

Cyber-physical systems
Cyber-physical systems (CPS) are created by the networking of embedded systems via communications networks. Cyber-physical systems are thus characterized by a link between real (physical) objects and processes on the one hand, and information-processing (virtual) objects and processes on the other – via open, in some cases global, permanently interconnected information networks such as the internet.

Debt capital
Debt capital is provided to companies by capital investors for a set period. In return, the investors expect the capital to be repaid with interest. Before providing debt capital, bankers require adequate planning of reliable future operating results and/or the provision of collateral in order to ensure the servicing of a loan.

DFG programme allowance
The DFG programme allowance serves to cover the indirect project costs related to DFG funding. It currently stands at 22 percent.

E-government
E-government (electronic government) means using information and communication technologies via electronic media to run governmental and administrative processes. In e-government, public services and administrative matters are digitalized and made available online.

Early stage
'Early stage' describes the financing of a company's early-phase development – beginning with the funding of research and product design (seed phase), continuing with the formation of the business until the beginning of operational business activities, and including product development and initial marketing (start-up phase). The seed phase is limited to R&D up to market maturity and the initial implementation of a business idea with a prototype; during the start-up phase a business plan is drafted, and production and product marketing begin.

Externalities
Externalities are defined as impacts of economic activities on third parties for which no compensation is paid.

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) to define key concepts such as 'research' and 'development'. The results of these discussions formed the basis of the first Frascati Manual. The Frascati Manual has been revised several times since then. The most recent edition dates from 2015.

Full-time equivalent
Full-time equivalents correspond to the number of employment relationships converted to full-time positions.

Gross domestic product
Gross domestic product (GDP) is defined as the total value of all goods produced and services provided in a country's economy within a year. It is not relevant in this context whether domestic or foreign actors are involved in the production of GDP; the only important factor is where the value is added. GDP is an indicator of the economic performance of an economy by international comparison.

High-Tech Strategy (HTS)
The High-Tech Strategy is a policy initiative by the Federal Government to integrate innovation funding across all federal ministries. The current HTS 2025 was adopted by the Federal Cabinet in September 2018.

Higher Education Pact 2025
The Higher Education pact 2025 is an agreement between the Federal and Länder governments which aims, on the one hand, to provide a range of study courses that is in line with demand and, on the other, to intensify competition for research funding by financing the DFG programme allowance. The Higher Education Pact 2025 expires at the end of 2020. The follow-up agreement is the 'Contract for the Future Strengthening of Higher Education and Teaching' (cf. separate entry).

High-value technology
High-value technology refers to R&D-intensive goods (cf. separate entry) in the production of which an annual average of more than three, but not more than nine percent of turnover is spent on research and development.

Innovation in Higher Education Teaching
The administrative agreement on 'Innovation in Higher Education Teaching' between the Federal Government and the Länder aims to support tertiary education institutions in the quality-oriented further development of studying and teaching. The administrative agreement was concluded for an indefinite period of time on the basis of Article 91b (1) of the Basic Law and replaces the Quality Pact for Teaching as from 2021. In order to implement the objectives set out in the administrative agreement, the Federal Government and the Länder will finance a legally dependent organizational unit.

Innovation expenditure
Innovation expenditure includes all R&D expenditure (internal plus external) and other internal and external expenditure necessary to implement innovation projects. This includes, for example, conceptual work, production preparation, market research and marketing concepts, further training and the acquisition of fixed assets for innovation.

Innovation intensity
Innovation intensity is defined as innovation expenditure relative to a company's turnover in a corresponding year.

Innovation system
An innovation system is a network of institutions in the public and private sectors whose activities and interactions initiate, modify and implement new technologies. The speed of technological change in different countries and the effectiveness of companies in global economic competition not only depend

on the extent of R&D and other technical activities, but are also influenced by the way in which the available resources are managed and organized both by the companies themselves and at national level (Freeman 1987).

Innovator rate
The innovator rate measures the number of companies that have introduced at least one product innovation (i.e. a new or significantly improved product) or process innovation (i.e. a new or significantly improved process) in the preceding three-year period as a percentage of all companies.

Intellectual property rights
Intellectual property refers to intangible goods such as ideas, concepts or inventions. These assets are legally protected if the legal system assigns corresponding rights, such as patents or copyrights. The holder of such a right can be the patent applicant or the creator of a copyrighted work.

Internet of Things
The use of information and communication technologies in everyday objects has created connections between the real world and the virtual world. This networking of devices and people is called the Internet of Things (IoT), or the Internet of Things and Services. Examples include computer systems embedded into clothing which monitor the wearer's vital functions, imprinted chip codes which make it possible to track packages via the internet, and refrigerators that autonomously order foodstuffs when stocks are low.

Joint Task of the Federal Government and the Länder for the Improvement of Regional Economic Structures
The central instrument of regional policy in Germany is the Joint Task of the Federal Government and the Länder for the Improvement of Regional Economic Structures (GRW). Since 1969, the Federal Government has been taking its share of responsibility for balanced regional development in Germany within the framework of the GRW. The cooperation between the Federal Government and the Länder in the GRW is regulated constitutionally by Article 91a of the Basic Law and specified by the GRW Act.

Knowledge-intensive sectors
The knowledge-intensive sectors encompass R&D-intensive industries (cf. separate entry) and knowledge-intensive services (cf. separate entry).

Knowledge-intensive services
Knowledge-intensive services are primarily characterized by an above-average percentage of employees who have tertiary education qualifications.

Later stage
'Later stage' describes the financing of business expansion in a young company which is already generating turnover and whose product is ready for the market.

National funding system for structurally weak regions
Following the expiry of the Solidarity Pact II (cf. separate entry), the Federal Government has been supporting structurally weak regions since the beginning of 2020 under a national funding system. The national system aims to improve economic performance in structurally weak regions. It comprises 22 funding programmes from different federal departments – including six programmes of R&I policy.

Pact for Research and Innovation
The Pact for Research and Innovation (PFI) regulates increases in the funding of Germany's five non-university science and research organizations by the Federal and Länder governments. In return, the non-university science and research organizations undertake to implement selected research policy goals. The currently valid third PFI will be replaced by PFI IV from 2021, which will run until 2030.

Patent family
A patent family denotes a group of patents or patent applications that are directly or indirectly connected by a common priority, have at least one common priority, or have exactly the same priority or combination of priorities.

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) that was established in 1969. Instead of filing several separate national or regional applications, inventors from PCT countries can submit a single advance patent application to the WIPO or another registered authority. This enables them to obtain patent protection in all 148 contracting countries. The priority date of the patent is the date on which the application is submitted to the WIPO. The final

decision on the countries where patent protection is to be granted must be taken within a period of 30 months (or 31 months at some authorities like the EPA). National or regional patent offices are nevertheless still responsible for the actual granting of patents.

Quality Pact for Teaching

The 'Programme for Better Study Conditions and Improved Teaching Quality' (Quality Pact for Teaching) is an agreement between the Federal Government and the Länder aiming to improve the tertiary education institutions' staffing levels for teaching, support and counselling and to further qualify existing staff. The Quality Pact for Teaching expires at the end of 2020. It will be followed by the administrative agreement on 'Innovation in Higher Education Teaching' (cf. separate entry).

R&D employee productivity

R&D employee productivity measures the number of triadic patent applications (cf. separate entry) per 1,000 R&D employees. It is an indicator of how successful R&D employees are in developing new, patentable ideas.

R&D-intensive goods

R&D-intensive goods comprise cutting-edge-technology (cf. separate entry) goods and high-value-technology (cf. separate entry) goods.

R&D-intensive industry

R&D-intensive industry involves cutting-edge technology (cf. separate entry) sectors and high-value technology (cf. separate entry) sectors.

R&D intensity

R&D intensity is defined as expenditure on research and development (R&D) as a percentage of either a company's or a sector's total turnover, or of a country's gross domestic product.

Rate of qualified school-leavers

This indicator measures the number of school-leavers qualified for higher education in a given year as a percentage of the population aged between 18 and 20 inclusive. The average of the last three years is taken as the size of the population in this age group.

RCA index

The RCA (revealed comparative advantage) index describes the relation between exports and imports in a commodity group relative to the macroeconomic relation between exports and imports. For the purpose of mathematical representation, this ratio is logarithmized and the factor multiplied by 100.

Research and development (R&D)

Research and development (R&D) and research and innovation (R&I, cf. separate entry) are not used synonymously. The OECD's Frascati Manual (cf. separate entry) defines R&D as systematic, creative work aimed at expanding knowledge – also with the objective of developing new applications. The term R&D covers the three areas of basic research, applied research and experimental development.

Research and innovation (R&I)

Research and innovation (R&I) and research and development (R&D, cf. separate entry) are not used synonymously. R&D represents only one aspect of R&I activities. According to the definition given in the OECD's Oslo Manual (cf. separate entry on OECD), innovations include the introduction of new or essentially improved products (goods and services) or processes.

Social innovations

Social innovations are changes in the way technologies are used – or changes in lifestyles, business or financing models, working practices, or forms of organization; in principle they represent changes in social practices. Social innovations can be both complementary to and a consequence of a technological innovation – or be completely independent of such an innovation.

Solidarity Pact II

The Federal Government's Solidarity Pact II channelled a total of €156 billion to the east German Länder and Berlin between 2005 and 2019. It consisted of two parts – Basket I and Basket II. Basket I comprised federal supplementary grants to meet special needs (Sonderbedarfs-Bundesergänzungszuweisungen, SoBEZ) under the Financial Equalization Act, amounting to around €105 billion, which served to overcome infrastructure deficits caused by Germany's partition and to offset the comparative municipal financial weakness. Basket II contained about €51 billion in so-called disproportionate funds, which flowed into seven pre-defined policy areas: 'Economy', 'Innovation, R&D, Education', 'Transport', 'Housing and Urban Development', 'EU Structural Funds', 'Clearing and Restoring Contaminated Sites' and 'Sport'. Following the expiry of Solidarity Pact II, the Federal

Government has been funding structurally weak regions nationwide since the beginning of 2020 under a 'National funding system for structurally weak regions' (cf. separate entry).

Spatial planning regions
Spatial planning regions (ROR) make up the observation and analysis grid of federal spatial planning. They largely coincide with the Oberbereiche of the Länder; they are therefore also almost identical to the latter's planning regions. In principle, they describe an economic centre and its surrounding area, with particular reference to commuter networks.

Start-up intensity
Start-up intensity indicates the annual number of start-ups per 10,000 employable people and is an indicator of the willingness to start a business.

Start-up radar
The start-up radar of the Stifterverband für die Deutsche Wissenschaft (Donors' Association for German Science) and the Heinz Nixdorf Foundation compares university/college profiles in start-up funding at German tertiary education institutions.

Start-up rate
The start-up rate is the number of start-ups in relation to the total number of companies.

Start-ups
A start-up is a newly founded company with an innovative business idea.

Total factor productivity
Total factor productivity indicates the part of economic growth that is not based on an increase in such factors of production as labour and capital. It is thus a residual which is usually associated with technological progress or increases in efficiency.

Transnational patent applications
Transnational patent applications are applications in the form of patent families which include at least one application filed with the World Intellectual Property Organization (WIPO) via the PCT procedure, or one application filed with the European Patent Office. Such patents are particularly important for the export-based German economy, since they secure the protection of inventions beyond the domestic market.

Triad countries
Triad countries are the three strongest economic regions in the world at the time when the concept was introduced in the early 1990s, i.e. the North American Free Trade Area (NAFTA), the EU and industrialized East Asia (Hong Kong, Japan, Singapore, South Korea and Taiwan).

Triadic patent applications
Triadic patent applications are patent applications filed both at the US Patent Office and at the European and Japanese Patent Offices. They are regarded as an indication of expansion intentions in innovative markets.

University entry rate
This figure refers to the number of new tertiary students (first-degree students) as a percentage of the relevant age group. The indicator illustrates the change in relative participation in higher education. The university entry rate is calculated as the number of new tertiary students in a given age group and year divided by the population in that age group and year; the percentages are subsequently added up.

Value added
Value added is the total of all factor income (wages, salaries, interest, rental and lease income, sales profits) in a given period in the national accounts and 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 intermediate inputs received from other companies in the same period.

Venture capital
Venture or risk capital refers to initial capital for start-up entrepreneurs and young companies. It also includes funding used to strengthen the equity-capital bases of small and medium-sized enterprises, enabling them to expand and to implement innovative, sometimes very risky projects. Venture-capital investments are also associated with a high risk for the capital investors. 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). A distinction is made between three phases of start-up companies: seed stage, start-up stage and later stage.

Economic sectors in R&D-intensive industries and knowledge-intensive commercial services[349]

D 4

R&D-intensive industrial sectors within the Classification of Economic Activities, 2008 edition (WZ 2008) (4-digit classes)

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 motor vehicles
29.32 Manufacture of other parts and accessories for motor vehicles
30.20 Manufacture of railway locomotives and rolling stock
32.50 Manufacture of medical and dental instruments and supplies

Knowledge-intensive commercial services within the Classification of Economic Activities, 2008 edition (WZ 2008) (3-digit classes)

Knowledge-intensive services

Emphasis on finance 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 Computer programming, consultancy and related activities
631 Data processing, hosting and related activities, web portals
639 Other information service activities n.e.c.

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 Activities of head offices
702 Management consultancy activities
722 Research and experimental development on social sciences and humanities
731 Advertising
732 Market research and public opinion polling
821 Office administrative and support activities

Emphasis on media and culture

581 Publishing 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 Specialized design activities
743 Translation and interpreting activities
823 Organization of conventions and trade shows
900 Creative, arts and entertainment activities
910 Libraries, archives, museums and other cultural activities

Emphasis on health

750 Veterinary activities
861 Hospital activities
862 Medical and dental practice activities
869 Other human health activities n.e.c.

Recent studies on the German innovation system

D 5

The Commission of Experts for Research and Innovation (EFI) regularly commissions studies on topics that are relevant to innovation policy. These studies can be accessed via the EFI website www.e-fi.de in the series 'Studies on the German innovation system'. The findings are integrated into the Report of the Commission of Experts.

1-2020
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List of sources: infocharts

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Infochart B 1
East Germany as a location for innovation – 30 years after reunification

1) Source: Braun et al. (2013).

2) Source: Rammer et al. (2020b) and own calculations based on ZEW data dated 7 November 2019. The figures presented for the innovation indicators are three-year moving averages for the years 2015 to 2017.

Infochart B 2
Cybersecurity

1) Source: ZEW Economic Survey of the Information Sector 3rd Quarter 2019. Calculations in ZEW (2020).

2) Source: ZEW Economic Survey of the Information Sector 3rd Quarter 2019. Calculations in ZEW (2020).

Infochart B 3
Exchange of knowledge and technology between Germany and China

1) Source: Gehrke et al. (2020b).

2) Source: Conlé et al. (2018). Data for APRA monitoring using data from Destatis and the World Bank

3) Source: Web of Science. Calculation by DZHW (German Centre for Higher Education Research and Science Studies).

4) Source: EPO (PATSTAT). Calculations by Fraunhofer ISI in Neuhäusler et al. (2020)

5) Source: https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#

6) Source: Conlé et al. (2018). Data for APRA monitoring using data from Destatis and the World Bank.

7) Source: Web of Science. Calculation by DZHW (German Centre for Higher Education Research and Science Studies).

8) Source: EPO (PATSTAT). Calculations by Fraunhofer ISI in Neuhäusler et al. (2020)

9) Source: Federal Statistical Office (2019a) and Federal Statistical Office (2019b).

10) Source: OECD (2017).

11) Source: Heinrichs et al. (2020).

12) Source: Dürr et al. (2020: 9) on the basis of data from the Deutsche Bundesbank.

13) Source: Dürr et al. (2020: 9) on the basis of data from the Deutsche Bundesbank.

D 8 Endnotes

A 1

1 Cf. Gehrke et al. (2020b).

2 The HTS 2025 states: "Together with the Länder and the private sector, we have set ourselves the goal of continuing the upward trend in investment in R&D and spending at least 3.5 percent of gross domestic product (GDP) on it by 2025." Cf. Bundesregierung (2018a: 4), own translation.

3 Cf. in the following on the Law on Tax Incentives for R&D (Forschungszulagengesetz): Bundesanzeiger (2019b), Deutscher Bundestag (2019d), Deutscher Bundestag (2019e) and https://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/Schlaglichter/Forschung-Entwicklung/2019-11-06-Foerderung-Forschung.html (last accessed on 17 January 2020). The BMF expects a tax-revenue shortfall of about €1.4 billion per year. Cf. https://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/Schlaglichter/Forschungs-Entwicklung/2019-11-06-Foerderung-Forschung.html (last accessed on 17 January 2020). According to the decision recommendation and report of the financial committee, tax revenues are expected to fall by €5.6 billion between 2021 and 2024. Cf. Deutscher Bundestag (2019e).

4 The Commission of Experts already recommended the introduction of tax incentives for R&D in its first annual report. Cf. EFI (2008: 32ff.). The Commission of Experts presented concrete options for tax-based R&D funding in its 2017 report. Cf. EFI (2017: 108ff.).

5 Funded R&D projects can be carried out as in-house research and/or as contract research, as a cooperation project between an eligible party and at least one other company, or as a cooperation project between an eligible party and one or more research and knowledge-dissemination organizations.

6 Eligible expenses include the employees' salaries subject to wage tax, which the employees receive directly from the employer, as well as the employer's expenses for securing the employee's future. The precondition is that the employees are entrusted with R&D activities. Eligible expenses also include a sole entrepreneur's own contributions to R&D projects. Here, a maximum of 40 working hours per week at a rate of €40 per working hour can be claimed for.

7 In the case of contracted R&D projects, the eligible expenditure can be up to 60 percent of the remuneration paid by the eligible party to the contractor.

8 In the case of companies that are affiliated with other companies, the upper limit applies to the affiliated companies together.

9 Concerning the liquidity effect, it would be advantageous to pay out the tax-based R&D funding directly to the eligible company. This was also initially provided for in the draft law. However, due to the requirements of European state aid law, the research subsidy is now offset against income tax or corporation tax. Cf. Deutscher Bundestag (2019d) and Deutscher Bundestag (2019e).

10 Cf. EFI (2018: 21f.).

11 Cf. Bundesregierung (2018a: 49).

12 Cf. o.V. (2018).

13 A founding committee was active prior to the start-up. The Federal Government appointed it in March 2019. Cf. https://www.bmbf.de/de/bundesregierung-setzt-gruendungskommission-fuer-die-agentur-fuer-sprunginnovationen-ein-8098.html (last accessed on 17 January 2020).

14 In this regard and in the following, cf. Bundesanzeiger (2019c).

15 These are in detail: artificial intelligence, autonomous and learning systems; quantum technology including the devices and equipment required for R&D; bio-based processes and solution approaches – biologization; novel cell- and gene-therapy approaches. Cf. Bundesanzeiger (2019c).

16 These are in detail: the shaping of the economy and Work 4.0; solutions for mobility and communication; contributions to a resource-efficient circular economy; further development of personalized medicine. Cf. Bundesanzeiger (2019c).

17 In the following, cf. BMWi and BMF (2019).

18 The Blockchain Strategy is to be reviewed and further developed at regular intervals as a 'learning strategy'. Cf. BMWi and BMF (2019: 5).

19 Specific issues of the Blockchain Strategy are to be discussed in this context.

20 These are in detail: ensuring stability and stimulating innovations: blockchain in the financial sector; maturing innovations: promotion of projects and regulatory test beds; enabling investments: clear, reliable framework conditions; applying technology: digitalized administrative services; spreading information: knowledge, networking and cooperation. Cf. BMWi and BMF (2019).

21 On the Federal Government's AI strategy, cf. Bundesregierung (2018b). Up to and including 2025, the Federal Government intends to provide a total of approximately €3 billion for the implementation of the AI strategy. The 2020 budget has distributed the second tranche of over €500 million for the AI sector among the individual plans. The distribution is as follows: Federal Chancellery: €10 million, BMI: €6.75 million, BMJV: €5 million, BMF €30 million, BMWi: €131 million, BMEL: €18 million, BMAS: €60.925 million, BMVI: €40 million, BMG: €30 million, BMU: €20 million, BMFSFJ: €12.5 million, BMBF: €154.5 million. Cf. https://www.cducsu.de/themen/wirtschaft-und-energie-haushalt-und-finanzen/bundeshaushalt-2020-mit-rekordsumme (last accessed on 17 January 2020).

22 Cf. Bundesregierung (2019).

23 These are in detail: BIFOLD – Berlin Institute for the Foundation of Learning and Data; Tübingen AI Centre – Competence Centre for Machine Learning; MCML – Munich Centre for Machine Learning, ML2R – Competence Centre Machine Learning Rhine-Ruhr; and ScaDS – Competence Centre for Scalable Data Services and Solutions Dresden/Leipzig. Cf. https://www.bmbf.de/de/kuenstliche-intelligenz-mehr-geld-fuer-die-forschung-9518.html (last accessed on 17 January 2020) and BMBF, Senatskanzlei Berlin, TUB (2020).

24 In addition to funding the Competence Centres for AI, the Federal Government plans to establish application hubs together with the private sector and users. According to the BMBF, the basic idea here is "that the respective actors in an application field [...] agree on a regional concentration of joint research and transfer activities". Specifically, the BMBF plans to establish application hubs in the fields of health/medicine and logistics. Cf. BMBF (2019), own translation.

25 According to the 'Interim Report: AI Strategy, One Year On' (Zwischenbericht ein Jahr KI-Strategie), the expansion plans drawn up by the centres in this context were positively assessed by the Scientific Advisory Board. Cf. Bundesregierung (2019). As part of the expansion of the competence centres, it was decided to merge the Berlin competence centres (BZML – Berlin Centre for Machine Learning and BBDC – Berlin Big Data Centre) to form BIFOLD – Berlin Institute for the Foundation of Learning. Cf. https://www.bmbf.de/de/kuenstliche-intelligenz-mehr-geld-fuer-die-forschung-9518.html (last accessed on 17 January 2020), BMBF, Senatskanzlei Berlin, TUB (2020) and https://bifold.berlin/ (last accessed on 17 January 2020).

26 Cf. https://www.bmbf.de/de/kuenstliche-intelligenz-mehr-geld-fuer-die-forschung-9518.html (last accessed on 17 January 2020).

27 Cf. Bundesregierung (2018b). The creation of AI professorships is also being promoted at the Länder level. For example, a total of 100 new professorships are to be created in Bavaria. Cf. https://www.forschung-und-lehre.de/politik/bayern-startet-wettbewerb-um-ki-professuren-2361(last accessed on 17 January 2020).

28 Cf. Bundesregierung (2019) and https://www.humboldt-foundation.de/web/alexander-von-humboldt-professur.html (last accessed on 17 January 2020).

29 According to the 'Interim Report: AI Strategy, One Year On' (Zwischenbericht ein Jahr KI-Strategie), the BMBF is in talks on this with the Länder where the competence centres are located. Cf. Bundesregierung (2019).

30 In June 2019, the BMBF launched a programme to support young female AI scientists. Cf. https://www.bmbf.de/foerderungen/bekanntmachung-2502.html (last accessed on 17 January 2020). In the pilot innovation competition called 'Energy-efficient AI system', the "participation, integration and strengthening of junior research groups" is one of the criteria used to select the competition entries to be funded. Cf. https://www.bmbf.de/foerderungen/bekanntmachung-2371.html (last accessed on 17 January 2020). Apart from implementing the AI strategy, the DFG is working to strengthen AI research in Germany. In October 2019, it decided to launch a strategic funding initiative in the AI field. With a budget of approximately €90 million, the DFG intends to fund up to eight research groups and 30 junior research groups. Cf. DFG (2019b).

31 Cf. on the GAIA-X project: BMWi and BMBF (2019).

32 Digital sovereignty here means the "possibility of independent self-determination of state and organizations" concerning the "use and design of digital systems themselves, the data generated and stored in them, and the processes described by them". Cf. BMWi and BMBF (2019: 7), own translation. For 'Examples of requirements from the user's point of view', cf. BMWi and BMBF (2019: 14ff.).

33 Although the Federal AI Association (KI Bundesverband) expressly welcomes the GAIA-X initiative, it criticizes the fact that the application level is not sufficiently taken into account and that the focus is on the technical infrastructure. Cf. https://ki-verband.de/gaia-x-ein-erster-kleiner-schritt-in-richtung-digitaler-souveraenitaet (last accessed on 17 January 2020).

34 The consortia participating in the innovation competition called 'Artificial Intelligence as a Driver of Economically Relevant Ecosystems' aimed to develop approaches for the application of AI in an economically relevant sector. The call for funding named ten areas of application in which the use of AI was expected to boost innovation in the German economy. In September 2019, 16 consortia were awarded prizes for their concepts and nominated for the so-called implementation phase. The implementation phase will be funded from 2020 onwards under the 'Development of digital technologies' (Entwicklung digitaler Technologien) funding framework, usually for three years. Cf. Bundesregierung (2019), Bundesanzeiger (2019a); BMWi (2019c), Bundesanzeiger (2019) and BMWi (2019e). The 'Energy-efficient AI System' is to be used as a pilot competition for SprinD GmbH. Within this framework, the BMBF is funding tertiary education institutions and public research institutions to enable them to showcase their ideas for energy-efficient electronic hardware for AI. The aim is to tap knowledge for high-tech solutions more quickly in this way. Cf. https://www.bmbf.de/foerderungen/bekanntmachung-2371.html (last accessed on 17 January 2020).

35 The task of so-called AI trainers is to pass on AI expertise to SMEs. They are located at the BMWi's SME 4.0 (Mittelstand 4.0) competence centres. The funding is provided under the name SME-Digital (Mittelstand-Digital). 33 AI trainers had started their work when the 'Interim report marking one year of the AI strategy' was published. According to the interim report, more are to be added successively. Cf. Bundesregierung (2019), BMWi and Bundesregierung (2019), and https://newsletter.mittelstand-digital.de/MDN/Redaktion/DE/Newsletter/2019/29/Meldungen/29_Aktuelles_KI-Trainer.html (last accessed on 17 January 2020). The AI map is an online map with application examples from the field of AI. Cf. Bundesregierung (2019) and www.ki-landkarte.de (last accessed on 17 January 2020). The 'Interim Report: AI Strategy, One Year On' also refers to the promotion of AI projects within the framework of the 'Central Innovation Programme for SMEs' (ZIM – Zentrales Innovationsprogramm Mittelstand). In addition,

the 'Innovation Award for Regulatory Test Beds' will be addressed. Cf. Bundesregierung (2019), www.zim.de (last accessed on 17 January 2020) and https://www.bmwi.de/Redaktion/DE/Wettbewerb/innovationspreis-reallabore.html (last accessed on 17 January 2020)

36 Cf. EFI (2019: chapter B 2).

37 The European Union has a market-compliant instrument for reducing CO_2 emissions: the European Union Emissions Trading System (EU ETS). However, only CO_2 emissions from the energy sector, energy-intensive industries, and inner-European air traffic are covered by the EU ETS. Implementing emission reduction targets in non-EU-ETS sectors is the responsibility of the Member States. Here the Fuel Emissions Trading Act comes in. Cf. in the following: http://www.gesetze-im-internet.de/behg/BJNR272800019.html (last accessed on 17 January 2020). On the Climate Protection Programme 2030, cf. BMU (2019).

38 Cf. http://www.gesetze-im-internet.de/behg/BJNR272800019.html (German, last accessed on 17 January 2020).

39 Cf. https://www.bundesrat.de/SharedDocs/pm/2019/015.html (last accessed on 17 January 2020), https://www.bundesregierung.de/breg-de/themen/klimaschutz/nationaler-emissionshandel-1684508 (last accessed on 17 January 2020) and https://www.bundesregierung.de/breg-de/themen/klimaschutz/co2-bepreisung-1673008 (last accessed on 17 January 2020).

40 Cf. EFI (2019: 78).

41 The law was passed in December 2019 based on the results of the Mediation Committee. Cf. https://www.vermittlungsausschuss.de/SharedDocs/pm/2019/015.html (last accessed on 17 January 2020), https://www.bundestag.de/dokumente/textarchiv/2019/kw46-de-klimaschutzgesetz-freitag-667244 (last accessed on 17 January 2020) and Deutscher Bundestag (2019c).

A 2

42 During the term of the PFI IV, the annual increase is financed by the Federal Government and the Länder in accordance with the distribution ratios defined for the individual science organizations. The deviations from the established ratios caused by PFI III will be gradually reduced during the term of the PFI IV. In this regard and in the following, cf. o.V. (2019c).

43 On the PFI III, cf. o.V. (2014a).

44 In this regard and in the following, cf. o.V. (2019d).

45 Cf. EFI (2019: 25f.).

46 On the Higher Education Pact 2020, cf. o.V. (2014b).

47 On the Higher Education Pact 2020, cf. o.V. (2014b).

48 The Commission of Experts already suggested in the past that quality-related indicators should also be taken into account when allocating funds. Cf. EFI (2019: 25f.).

49 Cf. on this also Vereinigung der Kanzlerinnen und Kanzler der Universitäten Deutschlands (2019).

50 In this regard and in the following, cf. o.V. (2019e).

51 In this regard and in the following, cf. o.V. (2019b) and https://www.bmbf.de/de/innovation-in-der-hochschullehre-9166.html (last accessed on 17 January 2020).

52 On the Higher Education Pact 2020, cf. o.V. (2014b).

53 In this regard and in the following, cf. o.V. (2019a).

54 Cf. EFI (2017: 36).

55 In a study commissioned by the BMBF, Prognos, KPMG, and Joanneum Research found that, in most cases, the BMBF project allowance of 20 percent only partially offset the costs caused by third-party-funded research. Cf. Prognos AG et al. (2014). At the time of the study, the DFG programme allowance, like the BMBF programme allowance, was 20 percent. In the meantime, it has been slightly increased and now stands at 22 percent.

B 1

56 Productivity is generally defined as the ratio between all outputs (goods and services) and inputs (factors of production). Cf. EFI (2018: 42).

57 Cf. Gropp and Heimpold (2019: 471), IWH (2019: 8) and BMWi (2019d: 20f.). East Germany includes Berlin here.

58 Cf. Gropp and Heimpold (2019: 471). Productivity is defined here as gross domestic product (GDP) per employed person.

59 Cf. BMWi (2019d: 21) and IWH (2019: 8).

60 Belitz et al. (2019) explain that east Germany is behind in terms of productivity primarily because of the predominance of rural areas. The BMWi (2019d) attributes the shortfall not only to east Germany's lower settlement density and more rural character, but inter alia also to the fragmented nature of the east German economy, the lower industrial density and the widespread lack of medium-sized world market leaders and specialized supplier industries with high levels of innovative strength and value creation. The IWH (2019), on the other hand, concludes that the deviations cannot be explained by structural differences alone, but also by existing productivity backlogs of east German companies compared to equally large west German companies. However, Alecke et al. (2010) show for an earlier period that the productivity differences between east and west German companies are only very small when one takes into consideration not only company size but also other structural characteristics.

61 R&D-intensive industry is made up of the industrial sectors of high-value technology and cutting-edge technology. Industries with cutting-edge technologies include all sectors of industry that spend an annual average of more than 9 percent of their turnover on research and development (R&D) to produce goods. Industries with high-value technology include all sectors of industry that invest an annual average of between 3 and 9 percent of their turnover in R&D to produce goods. Cf. EFI (2019: 155 and 157).

62 Cf. Rammer et al. (2020b: 26).

63 Cf. BMWi (2020b) and Rammer et al. (2020b: 26).

64 Cf. Ihle et al. (2020).

65 The analysis is based on data from the ZEW Mannheim Innovation Panel (Mannheimer Innovationspanel, MIP). All analyses based on extrapolated values refer to companies with five or more employees in the reporting population of the innovation survey. When comparing the innovation indicators over the long term, it should be noted that the sectoral composition of the MIP sample has changed over time and that some questions and definitions

of the innovation indicators have been slightly adjusted. The reporting unit of the innovation survey is usually the legally independent company. Innovation activity is basically measured at the company's headquarters. In the case of multi-sector companies, the activities of the individual operating sites are assigned to the company's headquarters. It should therefore be borne in mind that legally non-independent branches in east Germany are not included in the figures for east Germany. For further information, cf. Rammer et al. (2020b: 12f.).

66 Cf. in the following Ihle et al. (2020).

67 From 1997 to 2017, per capita R&D expenditure in east Germany increased by 133 percent in the public sector and by 96 percent in the business sector. Over the same period, R&D employment in east Germany rose by 40 percent in the public sector and by 17 percent in the business sector. Cf. Ihle et al. (2020).

68 Per capita R&D expenditure in west Germany rose from €568 in 1997 to €1,306 in 2017. R&D employment increased from around 380,000 full-time equivalents to around 582,000 full-time equivalents over the same period. Cf. Ihle et al. (2020).

69 In west Germany, per capita R&D expenditure rose by 136 percent in the business sector between 1997 and 2017. R&D employment in the business sector in west Germany increased by 58 percent in the same period. Cf. Ihle et al. (2020).

70 Cf. Ihle et al. (2020).

71 Cf. Eurostat (2019).

72 The corresponding shares in west Germany were 11 percent and 16 percent. Cf. Ihle et al. (2020).

73 In the period from 1997 to 2017, the share of total public R&D expenditure that went to east Germany fluctuated between 28 and 31 percent. In this regard and in the following, cf. Ihle et al. (2020).

74 Measured by R&D expenditure per capita, the order is the same: the highest grants were received by Berlin with €462 per capita, Saxony with €236 per capita and Brandenburg with €210 per capita.

75 In the case of process innovations, the achieved average reduction in unit costs should be used as a measure of implementation success. For information on this indicator, cf. Rammer et al. (2020b).

76 The Entropy Balancing multivariate weighting procedure was used. Note that changes in east Germany's structure can also lead to changes in the behaviour of east German companies. In this regard and in the following, cf. Rammer et al. (2020b: 39f.). The number of observations is different for each innovation indicator and for each observation year. In 2017, for example, the matching analysis was based on 7,217 observations for innovation intensity and 16,953 observations for the share of innovation-active companies. Cf. written information provided by ZEW dated 7 January 2020.

77 In this regard and in the following, cf. Rammer et al. (2020b) and ZEW (2019).

78 In addition to other structural features, innovation funding could also play a role. However, if innovation funding is seen as a structural feature in the matching analysis, the fact that the company structure can have repercussions on this structural feature would have to be taken into account. Furthermore, information on public funding for innovation is only available for selected years and only for innovation-active companies.

79 Here and in the following, the figures on the non-structurally adjusted and structurally adjusted innovation input and innovation output indicators are always three-year moving averages of the previous three years. This means that the value for 2017, for example, is the average of the values for 2015, 2016 and 2017.

80 Cf. own calculations based on ZEW data from 7 November 2019. Cf. also Rammer et al. (2020b: 16).

81 Cf. ZEW data from 19 November 2019 and Rammer et al. (2020b: 109).

82 Cf. own calculations based on ZEW data from 7 November 2019. Cf. also Rammer et al. (2020b: 15f.).

83 Cf. ZEW data from 19 November 2019 and Rammer et al. (2020b: 109).

84 Cf. own calculations based on ZEW data from 7 November 2019. Cf. also Rammer et al. (2020b: 17f.).

85 Cf. ZEW data from 19 November 2019 and Rammer et al. (2020b: 109).

86 For possible reasons for the sharp decline in the innovator rate, cf. EFI (2018: chapter B 1).

87 Cf. own calculations based on ZEW data from 7 November 2019. Cf. also Rammer et al. (2020b: 18f.).

88 Whereas the product innovator rates are currently still converging, the deviation in process innovator rates has tended to widen again since the beginning of the 2010s. Cf. in this regard and in the following, ZEW data from 19 November 2019 and Rammer et al. (2020b: 110).

89 Cf. own calculations based on ZEW data from 7 November 2019. Cf. also Rammer et al. (2020b: 20f.). The figures on the percentages of turnover generated by product innovations refer to the period from 1999 to 2017. The figures on the shares of turnover from imitative innovations and market novelties refer to the period from 2000 to 2017.

90 Cf. ZEW data from 19 November 2019 and Rammer et al. (2020b: 110).

91 The Federal Institute for Research on Building, Urban Affairs and Spatial Development (Bundesinstitut für Bau-, Stadt- und Raumforschung, BBSR) undertakes a spatial typification of regions. For this purpose, the regions are delimited at the municipal level. The concept of spatial typology is based on studies of the location of areas, classified according to their potentially achievable daily population, as well as the settlement of areas, classified according to population density and the percentage of the area that is settled. On the one hand, a distinction is made between the four types of location: very central, central, peripheral and very peripheral; on the other hand, the three types of settlement are predominantly urban, partly urban and rural. Cf. https://www.bbsr.bund.de/BBSR/DE/Raumbeobachtung/Raumabgrenzungen/deutschland/gemeinden/Raumtypen2010_vbg/raumtypen2010_node.html (last accessed on 17 January 2020). Only the results by settlement type are presented here. Predominantly urban regions are referred to below as urban regions for reasons of better readability. However, the results by location type are similar. Cf. in this regard, Rammer et al. (2020b: 74ff.).

92 Cf. https://www.bbsr.bund.de/BBSR/DE/Raumbeobachtung/Raumabgrenzungen/deutschland/gemeinden/Raumtypen2010_vbg/raumtypen2010_node.html (last accessed on 17 January 2020).

93 Exceptions to this are the differences in the share of innovation-active companies and the share of turnover from imitative innovations. These are about the same size in the east and west. As regards the size of the differences, cf. Rammer et al. (2020b: 75ff.). The regression analyses contain structural characteristics of the company (size, age and sector), as well as indicator variables for the type of area where the enterprise is located. The innovation performance by settlement type is considered here for the period from 1992 to 2017. In this regard and in the following, cf. Rammer et al. (2020b: 74ff.).

94 Cf. EFI (2019: 110).

95 In 2015, Berlin accounted for around 38 percent of the east German triadic patent applications. In this regard and in the following, cf. Ihle et al. (2020).

96 Triadic patent applications per 100,000 inhabitants in east Germany rose from 11.1 in 2001 to 15.1 in 2015. In west Germany, they increased from 36.3 to 38.6 over the same period.

97 The average for the remaining east German Länder was 11.3 in 2015. Cf. Ihle et al. (2020).

98 The development of R&D employee productivity was not linear. In both east and west Germany it rose between 2001 and 2007. Since then, it has declined continuously in both parts of the country. The decline in west Germany was much more pronounced than in east Germany. Cf. Ihle et al. (2020).

99 Cf. EFI (2017: chapter A 4) and EFI (2019: chapter B 1).

100 Cf. EFI (2017: chapter A 4).

101 R&D-intensive industry is made up of the industrial sectors of high-value technology and cutting-edge technology. Knowledge-intensive services comprise the fields of technology-oriented services and non-technical advisory services.

102 Cf. Metzger (2019), Bersch et al. (2020) and Bersch (2019).

103 In east Germany, the number of start-ups in the knowledge-intensive sectors fell by 45 percent between 1997 and 2018 (from 6,594 to 3,624), and by 39 percent in west Germany (from 28,828 to 17,664). With 1,932 start-ups, Berlin accounted for more than half of the start-ups in east Germany's knowledge-intensive sectors. In this regard and in the following, cf. Ihle et al. (2020).

104 In 1997, 6,132 start-ups were founded in knowledge-intensive services in east Germany. In 2018, the number of start-ups in the knowledge-intensive services in east Germany amounted to only 3,386. In west Germany, the number of start-ups fell from 26,557 (1997) to 16,652 (2018). An exception is Berlin as a very dense agglomeration. In the past two decades, the number of start-ups here amounted to approximately 1,850 per year. Cf. Ihle et al. (2020).

105 In east Germany, Berlin's share of start-ups in R&D-intensive industry is very high, averaging 31 percent. In west Germany, the number of start-ups in R&D-intensive industry fell from 2,271 (1997) to 1,012 (2018). Cf. Ihle et al. (2020).

106 In the period between 1997 and 2018, the average start-up intensity in Berlin was 8.5. Another reason is the decline in the number of start-ups in east Germany, which was accompanied by a decline in the number of employable people. By contrast, in west Germany only the number of start-ups declined, while the number of employable people hardly changed over the period reviewed. If the number of employable people in east Germany had developed similarly to that in west Germany, the start-up intensity in east Germany would have fallen to 3.1. Cf. Ihle et al. (2020).

107 Between 1997 and 2018, the average start-up intensity in the knowledge-intensive sectors were 4.0 in Brandenburg, 3.0 in Mecklenburg-Western Pomerania, 4.2 in Saxony, 3.0 in Saxony-Anhalt and 3.5 in Thuringia. In west Germany it was 5.9 in the same period. Cf. Ihle et al. (2020).

108 In 1997, 1.21 fewer companies for every 10,000 employable people were founded in the knowledge-intensive sectors in east Germany than in west Germany. In 2018, the difference between east and west was only 0.57 start-ups. Cf. Ihle et al. (2020).

109 The decline in start-up intensity in knowledge-intensive services is mainly due to the decline in the east German rural Länder. Cf. Ihle et al. (2020).

110 In the R&D-intensive industry, the start-up intensity in 2018 was 0.27 in Berlin, 0.30 in Saxony-Anhalt and 0.28 in Thuringia. Cf. Ihle et al. (2020). In terms of the overall economy, the lowest start-up intensities nationwide in 2018 were in Saxony-Anhalt with 19.6 and Thuringia with 18.1 start-ups per 10,000 employable people. Cf. Bersch et al. (2020).

111 Cf. Lejpras (2014) and Stephan (2014).

112 This is interesting against the background that only 18 percent of students in Germany at tertiary education institutions are enrolled in east Germany. Cf. own calculations based on data from the Gründungsradar 2018. Cf. also Frank and Schröder (2018).

113 The support for start-ups, in particular regarding how they are embedded in tertiary education institutions in structural and institutional terms, has markedly improved at most institutions since 2012. Tertiary education institutions have also made improvements compared to 2012 in relation to the awareness of start-ups and support for start-up projects. In this regard, EXIST-funded tertiary education institutions lead the way. Cf. Frank and Schröder (2018: 2ff., 13 and 20).

114 Cf. EFI (2019: 48).

115 East Germany accounts for 112 of the 331 EXIST Transfer of Research projects throughout Germany. Cf. EFI (2019: 48).

116 97 of the 112 EXIST Transfer of Research projects in east Germany were funded in Saxony, Berlin and Thuringia. Cf. EFI (2019: 48). Funding is provided primarily for projects in the fields of materials technology, microelectronics/systems technology and biotechnology. Cf. own calculations based on BMWi/PtJ data from 2018.

117 Cf. www.exist.de/DE/Programm/Exist-Gruenderstipendium/inhalt.html (last accessed on 17 January 2020).

118 325 of the 716 EXIST Business Start-up Grants in east Germany were awarded to fellows at Berlin tertiary education institutions. Cf. EFI (2019: 48). The majority

of the EXIST Business Start-up Grants funded in east Germany are in the fields of software and internet/communication technologies. Cf. own calculations based on BMWi/PtJ data from 2018.

119 Cf. Rammer et al. (2020b: 47).

120 Cf. Günther et al. (2010: 8).

121 Cf. Rammer et al. (2020b: 47ff.).

122 In the period from 1996 to 2016, the share of innovation-active companies involved in innovation cooperation averaged 26 percent. In west Germany, the share during this period was 19 percent. In this regard and in the following, cf. own calculations based on ZEW data from 7 November 2019.

123 Cf. own calculations based on ZEW data from 7 November 2019. Cf. also Rammer et al. (2020b: 49).

124 In the period from 1996 to 2016, an average of 56 percent of east German innovation-active companies cooperated with tertiary education institutions. In west Germany this rate was 51 percent. During this period, an average of 35 percent of innovation-active companies in east Germany entered into cooperation with non-university research institutions in the context of innovation activities. In west Germany the rate was 30 percent. Cf. own calculations based on ZEW data from 7 November 2019. Cf. also Rammer et al. (2020b: 50).

125 In east Germany, the share of innovation cooperation with research institutions rose from 20 percent in 1996 to 48 percent in 2016. In west Germany, the rate increased from 15 percent (1996) to 45 percent (2016). Cf. own calculations based on ZEW data from 7 November 2019. Cf. also Rammer et al. (2020b: 50).

126 Over time, there has been a convergence between east and west Germany in innovation cooperation between innovation-active companies and both suppliers and customers. In 2016, 36 percent of innovation-active companies in east and west Germany had innovation cooperation agreements with suppliers. In 2016, too, the proportion of innovation-active companies that entered into innovation cooperation with customers was 48 percent in both east and west Germany. Cf. own calculations based on ZEW data from 7 November 2019. Cf. also Rammer et al. (2020b: 50).

127 In the period from 2012 to 2016, east German innovation-active companies were engaged in 73 percent of regional innovation cooperation. In west Germany the figure was 68 percent. Between 1996 and 2016, an average of 30 percent of innovation-active west German companies entered into an innovation cooperation agreement with a European cooperation partner. In east Germany the share was 20 percent. A similar picture emerges for innovation cooperation with partners from the USA and Asia. Cf. own calculations based on ZEW data from 7 November 2019. Cf. also Rammer et al. (2020b: 51).

128 Recently, there has been a clear shift from Länder-based to federal funding in both east and west Germany. In 2016, approximately twice as many east and west German innovation-active companies were supported by the Federal Government than by the Länder. Cf. Rammer et al. (2020b: 67f.).

129 Project funds that flowed to the east German Länder and Berlin via a recipient in the west German Länder (excluding Berlin) are not included. In this regard and in the following, cf. own calculations based on https://www.datenportal.bmbf.de/portal/en/Table 1.2.1.html (last accessed on 17 January 2020).

130 The formula for the disproportionate funds is: (benefits east/inhabitants east – benefits west/inhabitants west) * inhabitants east.

131 Solidarity Pact II (Solidarpakt II) consisted of two parts – Basket I and Basket II. Basket I comprised federal supplementary grants to meet special needs (Sonderbedarfs-Bundesergänzungszuweisungen, SoBEZ) under the Financial Equalization Act (Finanzausgleichsgesetz), amounting to around €105 billion, which served to overcome infrastructure deficits caused by Germany's partition and to offset the comparative municipal financial weakness. Basket II contained about €51 billion in so-called disproportionate funds, which flowed into seven pre-defined policy areas: these included 'Innovation, R&D, Education', 'Economy', 'Transport', 'Housing and Urban Development', 'EU Structural Funds', 'Clearing and Restoring Contaminated Sites' and 'Sport'. Cf. https://www.beauftragter-neue-laender.de/BNL/Navigation/DE/Themen/Bundesstaatliche_Solidaritaet/Bund_Laender_Finanzausgleich_und_Aufbau_Ost/Solidarpakt_II/solidarpakt_II.html and https://www.bundesregierung.de/breg-de/themen/deutsche-einheit/solidarpakt-ii-466752 (each last accessed on 17 January 2020). For detailed information on the individual funding measures in the 'Innovation, R&D, Education' policy field and the disproportionate federal funds to the east German Länder that flowed into this field, cf. Ihle et al. (2020).

132 In this regard and in the following, cf. Günther et al. (2010).

133 The annual figures on the share of subsidized companies refer to companies which have stated that they have received public funding in the previous three years. In this regard and in the following, cf. Rammer et al. (2020b: 63ff.) and ZEW data from 7 November 2019.

134 In 2016, the share of companies conducting research occasionally that received funding was 26 percent in east Germany and 14 percent in west Germany. Cf. Rammer et al. (2020b: 66).

135 Cf. Rammer et al. (2011: 7).

136 Cf. Kaufmann et al. (2019: 8).

137 Cf. Kaufmann et al. (2019: 53f.).

138 Cf. https://www.innovation-strukturwandel.de/de/159.php, https://www.innovation-strukturwandel.de/de/innovative-regionale-wachstumskerne---das-programm-1774.html and https://www.innovation-strukturwandel.de/ de/innoprofile---das-programm-1776.html (each last accessed on 17 January 2020).

139 Cf. inter alia BMBF (2005), Lo et al. (2006), Gorynia-Pfeffer and Möller (2012), Günther et al. (2012) and Kaufmann et al. (2019). For a summary, cf. Ihle et al. (2020).

140 Cf. Dr. Thielbeer Consulting (2015) and Fraunhofer IMW (2016).

141 Cf. Ihle et al. (2020).

142 Structurally weak regions are defined with the help of the regional indicator model of the Joint Task of the Federal Government and the Länder for the Improvement

of Regional Economic Structures (Bund-Länder-Gemeinschaftsaufgabe Verbesserung der regionalen Wirtschaftsstruktur, GRW). The labour market regions, which comprise one or more administrative districts, form the spatial basis. The GRW regional indicator identifies structurally weak regions on the basis of four indicators: the average unemployment rate for the years 2009 to 2012 (weighting: 45 percent), the gross annual wage per employee liable for social insurance contributions in 2010 (weighting: 40 percent), the employment forecast for 2011 to 2018 (weighting: 7.5 percent) and an infrastructure indicator (last revised: 30 September 2012, weighting: 7.5 percent). Cf. BMWi (2020b: 9). The current GRW funding area is expected to continue until the end of 2022. From 2023, a demographic component is to be integrated into the indicator model with a higher weighting. Cf. BMWi (2020a: 3).

143 In this regard and in the following, cf. BMI (2019) and BMWi (2020a). In September 2019, the Federal Government also presented the draft of a 'Structural Strengthening of Coal Regions Act' (Strukturstärkungsgesetz Kohleregionen), which was based on recommendations made by the 'Growth, Structural Change and Employment' commission, also known as the Coal Commission. According to the draft, science, research, teaching and education are also to be funded. This includes the establishment of research institutions. Cf. Deutscher Bundestag (2019f.).

144 Implementation is primarily based on the Budget Act and by adapting the guidelines of the programmes concerned. This has not yet been carried out in all cases. Cf. BMWi (2020a: 3).

145 Cf. BMWi (2020a) and BMI (2019: 37).

146 Cf. Deutscher Bundestag (2019f.), BMWi (2020a) and BMWi (2020b).

147 An example in the national funding system for structurally weak regions is REGION.innovativ (part of the Innovation and Structural Change programme family). Outside the national funding system, non-technical innovations are funded, for example, by the Innovation Programme for Business Models and Pioneer Solutions (Innovationsprogramm für Geschäftsmodelle und Pionierlösungen, IGP). This is a pilot scheme with its own administrative structure under the same budget title as ZIM. Cf. information provided by BMWi dated 15 January 2020, https://www.bmbf.de/foerderungen/bekanntmachung-2692.html (last accessed on 17 January 2020) and BMWi (2019a).

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148 Cf. ZEW (2020). 68.7 percent of the IT companies that have introduced product or process innovations in the past three years assess the need to protect their IT for innovation activities as high or very high. The same applies to 59.7 percent of manufacturing companies that have introduced product or process innovations in the past three years.

149 Cf. ZEW (2020). 53.2 percent of the IT companies with product or process innovations in the past three years and 56.3 percent of the manufacturing companies with product or process innovations in the past three years expect a rise or sharp rise in the threat of cyberattacks on their company in the next three years.

150 Cf. ZEW (2020).

151 Cf. Hryhorova and Legler (2019) on the IT security industry and calculations by the ZEW.

152 These sectors include critical infrastructures as defined by the BSI Critical Infrastructure (KRITIS) Ordinance. Critical infrastructures are defined as services supplying the general public in the sectors mentioned, where failure or impairment would lead to considerable bottlenecks or to a threat to public safety, as well as facilities that are necessary for the provision of a critical service. Cf. BMI (2016) and BMI (2017). UP KRITIS (originally the KRITIS Implementation Plan) is a public-private partnership for the protection of critical infrastructures. Cf. https://www.kritis.bund.de/SubSites/Kritis/DE/Aktivitaeten/Nationales/UPK/upk_node.html (last accessed on 17 January 2020).

153 Cf. https://www.bsi.bund.de/DE/Themen/Cyber-Sicherheit/cyber-sicherheit_node.html (last accessed on 17 January 2020).

154 Cf. https://www.bsi.bund.de/DE/Themen/Cyber-Sicherheit/cyber-sicherheit_node.html (last accessed on 17 January 2020). So-called cyber-physical systems are thus also part of cyberspace. Cyber-physical systems include vehicles, medical equipment or machines containing IT that are digitally networked.

155 Cf. https://www.bsi.bund.de/DE/Themen/Cyber-Sicherheit/Empfehlungen/cyberglossar/Functions/glossar.html?cms_lv2=9817276 (last accessed on 17 January 2020).

156 The remaining 17 percent of attacks are of other types. Cf. BSI (2019a).

157 Cf. https://www.bsi.bund.de/DE/Themen/themen_node.html (last accessed on 17 January 2020).

158 Cf. Deutscher Bundestag (2017).

159 Cf. https://www.bsi.bund.de/DE/DasBSI/NIS-Richtlinie/NIS_Richtlinie_node.html (last accessed on 17 January 2020).

160 Cf. BSI (2019b)

161 Cf. https://www.faz.net/aktuell/wirtschaft/unternehmen/yahoo-drei-milliarden-accounts-von-datenklau-betroffen-15229889.html (last accessed on 17 January 2020).

162 Cf. https://www.handelsblatt.com/unternehmen/handel-konsumgueter/cyber-sicherheit-hacker-stehlen-daten-von-bis-zu-500-millionen-starwood-hotelgaesten/23703158.html (last accessed on 17 January 2020).

163 Websites such as the Hasso Plattner Institute's Identity Leak Checker https://sec.hpi.de/ilc/ (last accessed on 17 January 2020) or the University of Bonn's Leakchecker https://leakchecker.uni-bonn.de/ (last accessed on 17 January 2020) can be used to find out whether one's own e-mail address has been part of a leak.

164 The term 'malware' includes all computer programs that perform unwanted functions on a computer system. They include Trojans, worms and viruses. BSI status report (2019: 11).

165 BSI (2019b) based on data from the company AV-TEST. AV-TEST's evaluation also shows a stagnation in the

monthly new malware variants for the years 2018 and 2019.

166 DDoS attacks accounted for 18 percent of reported attacks, APT attacks for 12 percent, and other attacks for 17 percent. Cf. BSI (2019a).

167 Cf. BSI (2019c).

168 Cf. BSI (2019a).

169 For a description of digging cryptocurrencies, cf. also EFI (2019).

170 Cf. BSI (2012).

171 The survey was conducted within the framework of the ZEW business survey on the information economy in the 3rd quarter of 2019. The results are based on extrapolations of self-reports by 955 IT companies and 429 manufacturing companies. Cf. ZEW (2020).

172 The information sector includes companies in the sub-sectors IT hardware and IT services, media services and knowledge-intensive services.

173 Manufacturing includes companies in the sub-sectors chemicals and pharmaceuticals, mechanical engineering, vehicle construction and other manufacturing industries.

174 In the information economy, 42.9 percent of companies expecting the threat of cyberattacks to rise or rise sharply over the next three years are delaying existing innovation projects. By comparison, existing innovation projects are being delayed in 23.1 percent of the IT companies that do not expect such an increase. In the manufacturing sector, existing innovation projects are being delayed in 39.2 percent of companies that expect the threat of cyberattacks to rise or rise sharply over the next three years. This applies to 22.3 percent of manufacturing companies that do not expect such an increase.

175 48.8 percent of the IT companies and 56.7 percent of the manufacturing companies expect a rise or sharp rise in the threat of cyberattacks in the next three years. Cf. ZEW (2020).

176 According to an empirical study by the Alliance for Cybersecurity, cybersecurity is seen as a driver of innovation with which companies can raise their profile vis-á-vis the competition. Cf. BSI (2019a).

177 However, patent applications do not fully reflect innovation activities. For example, according to German patent law, the patenting of software is only possible under certain conditions. Cf. https://www.dpma.de/patente/patentschutz/schutzvoraussetzungen/schutz_computerprogramme/index.html (last accessed on 17 January 2020).

178 The analysis is based on 36,220 patent families of patent class G06F21 whose earliest application was between 2000 and 2017.

179 The development of transnational patent applications in the field of cybersecurity over time shows considerable parallels to that of transnational patent applications as a whole (cf. figure C 6-1).

180 A specialization in the field of cybersecurity exists if a country's transnational patents in the field of cybersecurity as a percentage of the total number of all transnational patents in this field worldwide exceeds a country's transnational patents across all fields as a percentage of the total number of all transnational patents worldwide. This is not the case in Germany. In 2017, German inventors held 6.8 percent of cybersecurity patents, which is below the number of transnational patents as a percentage of the global total (10.5 percent), cf. table C 6-2. By comparison, in the USA the share of transnational cybersecurity patents (30 percent) was higher than the country's share of all transnational patents (21.4 percent). In Israel, the share of transnational cybersecurity patents (2.7 percent) was also higher than its share of all transnational patents (0.9 percent). Chinese inventors' share of transnational patents in the field of cybersecurity was 18.7 percent in 2017, compared to an 18.0 percent share of transnational patents as a whole.

181 Cf. https://cybersecurityventures.com/cybersecurity-companies-list-hot-150/#hot-150/?view_15_per_page=150&view_15_page=1 (last accessed on 17 January 2020).

182 68 percent of German industrial companies with at least ten employees regard the lack of qualified IT security specialists as quite threatening or very threatening for the future IT security of their company. Cf. Bitkom (2018).

183 The analysis is based on job offers on the online platform LinkedIn. Cf. BluSpecs Innovation SL et al (2019).

184 For Germany there are indications of particular difficulties in filling vacancies for IT specialists in general. It takes an average of 130 days to fill a qualified IT post, compared to an average of 118 days to fill a post with a graduate or skilled personnel across all professions. Cf. BA (2019).

185 The StudyCheck portal currently lists 28 study courses on IT security. Cf. https://www.studycheck.de/studium/it-sicherheit (last accessed on 17 January 2020). Further study courses are currently being accredited. This compares to 318 degree courses in computer science. Cf. https://www.studycheck.de/studium/informatik (last accessed on 17 January 2020). The Federal University of Applied Sciences for Public Administration (HS Bund), in cooperation with the BSI, is offering a new and highly specialized dual course of study in 'Digital Administration and Cybersecurity' starting in the winter semester 2020/2021. Cf. https://www. bsi.bund.de/DE/Presse/Pressemitteilungen/Presse2020/Studiengang_Cyber_Security_100120.html;jsessionid=8379355138A4DA954E8C2188A210F5A2.2_cid369 (last accessed on 17 January 2020).

186 Cf. https://berufenet.arbeitsagentur.de/berufenet/faces/index;BERUFENETJSESSIONID=VliJXWytj5YLHfQStltNgAiN2Kh0Y93G7-lITG6hgSVgmtDWEC0U!1187035158?path=null/kurzbeschreibung/aktuelleszumberuf&dkz=7847 (last accessed on 17 January 2020).

187 Cf. https://www.gdv.de/de/themen/news/materialien-zum-download-43692 (last accessed on 17 January 2020).

188 Cf. KPMG (2019).

189 The authors of the study define e-crime as "the execution of white-collar crime using information and communication technology to the detriment of an individual, a company or an authority", KPMG (2019: 9).

190 Cf. Hillebrand et al. (2017). Instead of having cybersecurity safeguarded internally by their own employees, companies can also use external service providers. A large number of digital processes can be outsourced to cloud service providers, who are then also responsible for cybersecurity.

However, companies must have confidence in these cloud service providers to perform this task.

191 Cf. for example, Asghari et al. (2016) and Moore (2010).

192 Cf. https://www.cert-bund.de/wid (last accessed on 17 January 2020).

193 These include, for example, the Alliance for Cybersecurity founded by the BSI in 2012. With currently around 4,080 affiliated companies and institutions, the initiative aims to increase Germany's resilience to cyberattacks. Cf. https://www.allianz-fuer-cybersicherheit.de/ACS/DE/Ueber_uns/ueber_uns.html (last accessed on 17 January 2020).

194 Cf. Kleinhans (2015).

195 Cf. section 9 (2) of the BSIG.

196 Cf. European Commission (2019d).

197 Cf. https://ec.europa.eu/growth/single-market/goods/new-legislative-framework_de (last accessed on 17 January 2020).

198 Cf. Deloitte (2018).

199 Cf. https://www.gdv.de/de/themen/news/das-leistet-eine-cyberversicherung-31152 (last accessed on 17 January 2020)..

200 Cf. BIGS (2017).

201 The survey covers industrial companies with ten or more employees. Cf. Bitkom (2018).

202 Cf. KPMG (2019).

203 The German Act to Improve the Security of Information Technology Systems (IT Security Act) contains several amendments to the BSI Act, the Energy Industry Act, the Telemedia Act and the Telecommunications Act; it is thus an essential legal basis for cybersecurity. The Federal Government is currently working on an amendment to the IT Security Law.

204 Cf. https://www.bmbf.de/de/sicher-in-der-digitalen-welt-849.html (last accessed on 17 January 2020). A follow-up programme to the present Research Framework Programme on IT security is currently being planned. In the course of the year, the BMBF will develop future-relevant research fields in cooperation with experts from science, politics and society. This process is to be continued throughout the programme in order to be able to adapt funding priorities and instruments to current funding needs.

205 CISPA consists of Saarland University, the Max Planck Institutes for Computer Science (MPI-INF) and Software Systems (MPI-SWS), and the German Research Centre for Artificial Intelligence (DFKI). The researchers are working on solutions for the core problems of IT security and data protection in the digital society. The research priorities are oriented primarily towards the two lighthouse projects 'Big Data Privacy' and 'Usable Security for Mobile Systems'. https://kompetenz-it-sicherheit.de/ (last accessed on 17 January 2020).

206 KASTEL consists of the Karlsruhe Institute of Technology (KIT), the Fraunhofer IOSB and the FZI Research Centre for Information Technology. Under the motto 'Comprehensible security in the networked world', KASTEL confronts the challenges posed by the progressive networking of previously isolated systems. Of particular importance are the consequences of digitalization in the field of critical infrastructures, e.g. in the energy industry, in industrial production and in networked mobility, but also in 'intelligent' environments. https://www.kastel.kit.edu/ (last accessed on 17 January 2020).

207 CRISP is a research centre of the Fraunhofer SIT and IGD Institutes, the Darmstadt University of Technology and the Darmstadt University of Applied Sciences. In addition to its focus on computer science and technology, the work at CRISP involves interdisciplinary issues such as law, economics, psychology and ethics. CRISP's application-oriented profile includes technology transfer up to and including business start-ups. https://kompetenz-it-sicherheit.de/ (last accessed on 17 January 2020)

208 Cf. https://www.bmbf.de/de/athene-grosser-schritt-zu-mehr-it-sicherheit-10362.html (last accessed on 17 January 2020).

209 Cf. https://www.forschung-it-sicherheit-kommunikationssysteme.de/projekte/gruendungsinkubatoren (last accessed on 17 January 2020).

210 Cf. https://www.bmvg.de/de/aktuelles/-gemeinsame-cyberagentur-149966 (last accessed on 17 January 2020) and Deutscher Bundestag (2019a). For information on the budget of the ZITiS, cf. https://www.heise.de/newsticker/meldung/ Zitis-Budget-fuer-staatliche-Hacker-wird-2019-deutlich-erhoeht-4192291.html (last accessed on 17 January 2020).

211 Cf. Deutscher Bundestag (2019a).

212 The Federal Government describes the Cyber Agency's task with regard to procurement as follows: "By means of targeted commissioning oriented towards the Federal Government's needs, the Cyber Agency aims to achieve sustainable technological sovereignty in the field of cybersecurity for Germany in the medium to long term. Thus, the Cyber Agency will become a hinge between Germany's research landscape and the Federal Government in the field of cybersecurity." Deutscher Bundestag (2019a: 2).

213 Cf. https://www.bmvg.de/de/aktuelles/bundeskabinett-beschliesst-cyberagentur-27392 (last accessed on 17 January 2020).

214 Cf. https://www.bmwi.de/Redaktion/DE/Artikel/Digitale-Welt/it-sicherheit.html (last accessed on 17 January 2020).

215 Cf. https://www.it-sicherheit-in-der-wirtschaft.de/ITS/Navigation/DE/Ratgeber-und-Tools/IT-Sicherheitscheck/it-sicherheitscheck.html (last accessed on 17 January 2020).

216 Cf. https://www.it-sicherheit-in-der-wirtschaft.de/ITS/Navigation/DE/Ratgeber-und-Tools/IT-Sicherheitsnavigator/it-sicherheitsnavigator.html (last accessed on 17 January 2020).

217 Cf. https://www.awareness-im-mittelstand.de/ (last accessed on 17 January 2020).

218 Cf. https://www.it-sicherheit-in-der-wirtschaft.de/ITS/Navigation/DE/Ratgeber-und-Tools/Sensibilisierungskampagne/sensibilisierungskampagne.html (last accessed on 17 January 2020).

219 The third amendment to the BMBF's announcement of guidelines for the funding measure 'SME innovative (KMU innovativ): Information and Communication Technology (ICT)' dated 23 August 2012, led to the inclusion of the IT security field in the funding by KMU-innovativ. An evaluation of the funding measure in 2014 concluded that participation in KMU-innovativ strengthens innovative

action by SMEs. There was no specific evaluation for the field of IT security, however. Prognos AG (2014).

220 Cf. https://www.bsi.bund.de/DE/DasBSI/Leitbild/leitbild_node.html (last accessed on 17 January 2020).

221 https://www.bsi-fuer-buerger.de/BSIFB/DE/Empfehlungen/empfehlungen_node.html; https://www.bsi-fuer-buerger.de/BSIFB/DE/Service/Buerger-CERT/Buerger-CERT_node.html (last accessed on 17 January 2020). The importance of consumer protection as a task of the BSI was upgraded in the coalition agreement.

222 Cf. https://www.bsi.bund.de/DE/Themen/Cyber-Sicherheit/Empfehlungen/fuer_Wirtschaft/CS_Empfehlungen_node.html (last accessed on 17 January 2020).

223 Cf. https://www.bsi.bund.de/DE/DasBSI/Aufgaben/Bund-Laender-Koop/Bund_Laender_node.html (last accessed on 17 January 2020).

224 In November 2019, the CERT Alliance sent out 415 brief notes with up-to-date information on security gaps. In addition, CERT Alliance automatically evaluates data from service providers, operators of so-called sinkholes, which provide information about infections with malware. Sinkholes are servers to which malware communication is redirected, thus making it possible to analyse the malware communication. On this basis, the CERT Alliance can inform network operators about infections in their network area and work towards making the weak points secure.

225 In addition, the BSI publishes warnings in accordance with section 7 of the BSIG (BSI Act) when, although a product poses a high risk, the manufacturer has not taken timely or adequate measures to end the risk posed by its product. In 2019, the BSI published three reports in accordance with section 7 of the BSIG. Cf. https://www.bsi.bund.de/DE/Themen/Cyber-Sicherheit/Gefaehrdungslage/Warn_Par7_BSIG/Archiv/Archiv_ node.html and https://www.bsi.bund.de/DE/Themen/Cyber-Sicherheit/Gefaehrdungslage/Warn_Par7_BSIG/FAQ/FAQ_node.html (last accessed on January 2020).

226 Cf. https://www.sicher-im-netz.de/%C3%BCber-uns (last accessed on 17 January 2020).

227 Cf. European Commission (2019b).

228 Cf. Bundesnetzagentur (2019).

B 3

229 The statements and information in the remainder of this chapter refer to the People's Republic of China without Taiwan, since Taiwan has an R&I system that differs considerably from that of the People's Republic of China in terms of structure and governance.

230 Cf. Krumbein (2019); BMI (2018: 296ff.); Zenglein and Holzmann (2019: 8); European Parliament (2018: 15f.); U.S. Chamber of Commerce (2017: 7f.).

231 Cf. Heinrichs et al. (2020: 17ff., 58f.).

232 Cf. Kunze et al. (2018: 9ff.).

233 Cf. European Parliament (2018: 15); BDI (2019); Deutscher Bundestag (2019b).

234 Cf. BMBF (2015: 34).

235 Cf. BMI (2018: 297); BAFA (2019).

236 The following indicators refer to the People's Republic of China excluding Hong Kong and Taiwan.

237 Cf. Gehrke et al. (2020b: 56) and https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB# (last accessed on 17 January 2020).

238 Cf. https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB# (last accessed on 17 January 2020).

239 Cf. Conlé et al. (2018: 74). Research-intensive goods are goods produced by research-intensive industries with an R&D intensity of more than 3 percent. Cf. Gehrke et al. (2013: 6).

240 In the major industrialized countries, the share of basic research is between 11 and 25 percent. Cf. DCPI (2018: 16f.).

241 Cf. http://www.shanghairanking.com/ARWU2019.html and https://www.timeshighereducation.com/world-university-rankings/2020/world-ranking#!/page/0/length/25/sort_by/rank/sort_order/asc/cols/stats (last accessed on 17 January 2020).

242 China's funding policy in recent years has placed a strong emphasis on increasing the excellence of state research institutes and universities. Cf. Conlé et al. (2018: 61 and 65).

243 Despite the progress described, China ranks only 44th in the World Bank's Human Capital Index (2018). Less than 20 percent of the Chinese workforce had a tertiary-level qualification in 2017, compared to 30 to 40 percent in OECD countries. Cf. World Bank Group (2019).

244 Cf. Gu et al. (2016).

245 This calculation is based on a so-called fractional counting method. When a publication has several authors, only a fraction is attributed to each participating country according to its share in the total number of authors.

246 The excellence rate is defined as the proportion of a country's publications that are among the 10 percent of the most cited publications in the respective discipline. Cf. Waltman and Schreiber (2013).

247 Evaluation based on Web of Science. Calculations by the DZHW.

248 Cf. EPA (PATSTAT). Calculations by Fraunhofer ISI in Neuhäusler et al. (2020)

249 Cf. EPA (PATSTAT), OECD (MSTI), World Bank. Calculations by Fraunhofer ISI in Neuhäusler et al. (2020)

250 Cf. Conlé et al. (2018: 74); DCPI (2018: 19).

251 They reach only a third of the foreign citations of non-Chinese transnational patent applications. Cf. Boeing and Mueller (2019: 21).

252 Cf. European Commission (2018: 8).

253 Definition by the Deutsche Bundesbank. Cf. Deutsche Bundesbank (2019).

254 Cf. OECD (2008b: 87).

255 Cf. Deutsche Bundesbank (2019).

256 Cf. Deutsche Bundesbank (2005).

257 Cf. OECD (2008a: 1).

258 Cf. OECD (2008b: 237).

259 According to the Deutsche Bundesbank's statistics on direct investment, Chinese FDI in Germany peaked in the mid-2010s and declined significantly towards the end of the decade. It should be taken into account in this context that other data sources – such as Ernst & Young (2019), Felbermayr et al. (2019), Hanemann et al. (2019) and Bureau van Dijk, Zephyr-Datenbank – each assess the extent of Chinese direct investment in Germany differently than the direct investment statistics of the Deutsche

Bundesbank. The different results are caused by different definitions and delimitations. Cf. Dürr et al. (2020: 14f.). FDI data refer to the People's Republic of China including Hong Kong but excluding Taiwan.

260 Cf. BDI (2019); BMWi (2019b); Witt (2019).

261 Cf. Fuest et al. (2019a: 3).

262 Cf. Fuest et al. (2019a: 3).

263 Cf. Fuest et al. (2019a: 2f.) and Fuest et al. (2019b: 2).

264 This figure does not include the HNA Group's holding in Deutsche Bank, worth approximately €3.3 billion in 2016, because its holding remains below the 10 percent threshold. This also applies to Geely's stake in Daimler AG worth €8.9 billion in 2018. Cf. Dürr et al. (2020: 10).

265 Information of the ZEW dated 20 November 2019.

266 Of the 261 companies, 24 were no longer economically active at the beginning of 2019. Another four companies were taken over by other German or foreign companies after the Chinese takeover. Cf. Dürr et al. (2020: 19).

267 Cf. Dürr et al. (2020: 20f.).

268 Cf. Dürr et al. (2020: 23). The companies involved in insolvency proceedings were almost exclusively taken over 100 percent by Chinese investors. Only in one company there was a majority shareholding (information of the ZEW dated 20 November 2019).

269 Cf. Dürr et al. (2020: 23f.).

270 Cf. Jungbluth (2018: 17f.).

271 Total R&D expenditure as a percentage of turnover.

272 Cf. Dürr et al. (2020: 25f.).

273 Cf. Dürr et al. (2020: 29).

274 Consolidation is based on patent families that group together all applications based on the same invention. This prevents multiple counts. Cf. Dürr et al. (2020: 27).

275 Cf. Dürr et al. (2020: 28f.).

276 The Zephyr database from Bureau van Dijk serves as the basis for data. It contains information on corporate takeovers, stakes in companies and joint ventures (not included here). The data basis of the analysis is narrower than in the previous section, as minority interests are not included. The headquarters of the ultimate owner is deemed to be the investor's headquarters. Cf. Dürr et al. (2020: 30).

277 Own evaluation based on the full R&D survey of the years 2007, 2009, 2011, 2013, 2015 and 2017.

278 Cf. European Commission (2017).

279 Cf. https://www.bundesregierung.de/breg-de/bundeschancellor/better-protection-at-company takeovers-751596 (last accessed on 17 January 2020).

280 Cf. Bundesregierung (2018c).

281 Cf. Bundesregierung (2018c).

282 Cf. BMWi (2019b: 27f.).

283 Cf. https://ec.europa.eu/commission/presscorner/detail/en/IP_19_2088 and https://www.bmwi.de/Redaktion/DE/Artikel/Aussenwirtschaft/investitionspruefung.html (last accessed on 17 January 2020).

284 Cf. Hanemann et al. (2019: 15).

285 Cf. European Commission (2019c).

286 Cf. Dürr et al. (2020: 9).

287 Cf. National Development and Reform Commission (2018) and Weidlich (2019: 31).

288 Cf. Dürr et al. (2020: 48).

289 Cf. Mair et al. (2019: 3f.); European Commission (2019a: 49ff.); McBride and Chatzky (2019); https://www.bmwi.de/Redaktion/DE/Artikel/Aussenwirtschaft/laendervermerk-china.html (last accessed on 17 January 2020).

290 In the construction of this index, key emphasis is placed on the discriminatory nature of regulations, i.e. the existence of certain regulations only for foreign investors. The FDI index is based on the formally given regulations, but does not take into account how they are applied or implemented. Cf. https://stats.oecd.org/Index.aspx?datasetcode=FDI INDEX# (last accessed on 17 January 2020).

291 Cf. State Commission for Development and Reform and Ministry of Foreign Trade and Economic Cooperation (2019).

292 Cf. Scheil (2019), and Schaff and Schetelig (2019).

293 Cf. Schaub et al. (2019) and Qin (2019).

294 Cf. European Commission (2018: 10f.).

295 526 German companies operating in China were interviewed. Cf. Hildebrandt et al. (2019).

296 Technical discussions with company representatives held on 7 November 2019.

297 Cf. https://www.hrk.de/themen/internationales/internationale-zusammenarbeit/asien/china/studien-und-promotionsprogrammen/ (last accessed on 17 January 2020).

298 Cf. DAAD (2019: 32).

299 An overview of non-university research institutions' activities in China is provided by the reports of the non-university research organizations, which are prepared in conjunction with the monitoring reports for the Pact for Research and Innovation. Cf. DFG (2019a).

300 2018/19 winter semester: students who completed their schooling in Germany (Bildungsinländer/innen) 2,800 and students who completed their schooling outside Germany (Bildungsausländer/innen) 39,900. Cf. Statistisches Bundesamt (2019b).

301 Statistisches Bundesamt (2019a).

302 The number of German students in China has been stagnating since 2014 (2014: 8,200, 2016: 8,100, 2018: 8,079). Cf. Federal Statistical Office (2019a) and http://www.wissenschaftweltoffen.de/daten/index_html (last accessed on 17 January 2020).

303 The institution membership as specified on the publication is used as the starting point for the formation of a mobility indicator. Cf. OECD (2017: 128) and OECD (2013: 132).

304 Cf. OECD (2017: 128).

305 Joint publications are those in which at least one author has an affiliation with a German institution and one author has an affiliation with a Chinese institution.

306 Co-publications of German scientists with US scientists: 21,400; British scientists: 13,900; French scientists: 9,300 (2017). Cf. Heinrichs et al. (2020: 79).

307 Cf. Stepan et al. (2018: 53, 66 and 77).

308 Cf. Deutscher Bundestag (2019b: 4).

309 The US non-governmental organization Freedom House rates the degree of academic freedom in China at one on a scale from zero to four. Zero stands for the smallest and four for the greatest degree of freedom. Cf. https://freedomhouse.org/report/freedom-world/2019/china

(last accessed on 17 January 2020). Cf. also d'Hooghe et al. (2018).

310 Cf. Deutscher Bundestag (2019b).

311 Dual-use goods are goods, software and technology that are normally used for civilian purposes, but can also be used in the military field. Cf. BAFA (2019: 8).

312 Numerous German tertiary education institutions, for example, have committed themselves to conducting research exclusively for civilian purposes (civil clause).

313 Cf. BAFA (2019) and BfV (2016), as well as awareness-raising events organized by the BMWi and the Federal Office of Economics and Export Control (BAFA) specifically for research institutions and tertiary education institutions. Cf. Deutscher Bundestag (2019b).

314 Cf. Stepan et al. (2018).

315 Cf. BMBF (2015).

316 Cf. https://www.internationales-buero.de/de/china_kompetenz_an_deutschen_hochschulen.php (last accessed on 17 January 2020).

317 Cf. https://www.internationales-buero.de/de/china_kompetenz_an_deutschen_hochschulen.php (last accessed on 17 January 2020).

318 The study lists courses of study related to China at German universities as well as China-related courses with a business focus at universities of applied sciences. Cf. Stephan et al. (2018: 58 and 98ff.).

319 According to information provided by the universities and universities of applied sciences.

320 Cf. Stepan et al. (2018: 57).

321 Cf. https://chikoh.uni-hohenheim.de/ and https://internationales-buero.de/de/china_kompetenz_an_deutschen_hochschulen.php (last accessed on 17 January 2020).

322 Cf. https://www.intl.kit.edu/10825.php and https://www. internationales-buero.de/de/china_kompetenz_an_deutschen_hochschulen.php (last accessed on 17 January 2020).

323 Cf. Stepan et al. (2018: 60f.).

C 1

324 Cf. Gehrke et al. (2020a).

C 2

325 Cf. Gehrke et al. (2020b).

C 3

326 In this regard and in the following, cf. Rammer and Hünermund (2013).

327 In this regard, cf. also Rammer et al. (2020a).

328 Cf. Blind (2002).

329 Cf. ISO (2010) and https://www.iso.org/members.html (accessed on 16 December 2019).

C 4

330 This section and the following figures are based on Bersch et al. (2020).

331 Internal financing is rarely an option, as these companies initially generate little or no turnover with which to fund investment and pay for current expenditure. Borrowing outside capital in the form of bank loans is also difficult, as it is not easy for banks to assess the companies' success prospects.

332 Invest Europe is the European Association of Private Equity & Venture Capital Investors. Together with the European Data Cooperative (EDC), it runs a platform that collects data on private equity and venture capital. Invest Europe regularly supplies updated data on venture-capital investment based on the information in the EDC database and data from Eurostat and the International Monetary Fund. The data supplied is based on information from the national venture-capital associations, which receive their information from member surveys. The harmonized collection and processing of data ensures good international comparability.

333 This is the case when investing market participants are not registered as members of Invest Europe, or if an investor comes from outside Europe.

334 The Zephyr M&A database contains information on mergers and acquisitions (M&A), categorized according to private-equity, venture-capital and business-angel investments. The information includes the investment sum, the company that was invested in (portfolio company), and the investor. Since the Zephyr M&A Database primarily contains major investments, information from this database is complemented by the Majunke transaction database. It is made available by Majunke Consulting and covers venture-capital investment in Germany, Austria and the German-speaking part of Switzerland. It also contains information on the investment sum, the portfolio company and the investor, and also includes small investments. Since both databases also contain many other investments in companies in addition to venture-capital investments, each transaction is checked to determine with reasonable likelihood whether it is indeed a venture-capital investment. For this purpose, information from the Mannheim Enterprise Panel (MUP) is used about the (natural and legal) persons participating in a company.

335 Atypical investors are all those market participants who enter into direct venture-capital holdings, but whose core business is another. They may include, for example, asset managers, funds of funds, banks and insurers, as well as established companies.

C 5

336 However, the data from the individual countries are not fully comparable. For more details on this, cf. Müller et al. (2014).

337 In this regard, cf. Müller et al. on individual points (2013).

338 In this regard and in the following, cf. Bersch and Gottschalk (2019: 29).

339 The MUP comprises all the economically active companies in Germany, insofar as Creditreform documents them. It covers all business information available at Creditreform and also includes companies that no longer exist. In total, the MUP contains information on more than eight million companies that are economically active in Germany or have been economically active in the past. The ZEW brings these data into a panel structure and carries out

various quality controls (e.g. deletion of multiple entries, imputation of missing values on the economic sector, identification of closure characteristics). To calculate the total number of recent start-ups, extrapolations are made to take account of the time lag between a start-up event and its registration by Creditreform. Cf. Bersch et al. (2020) and https://www.zew.de/forschung/mannheimer-unternehmenspanel/ (last accessed on 17 January 2020).

340 An original, newly formed company is created when a business activity not previously exercised is begun and provides at least one person with their main source of income. Only original corporate start-ups are considered for the investigation of the start-up dynamics. Re-establishments of companies, the establishment of holding companies, or the creation of new commercial enterprises due to a move or secondary commercial operations are not regarded as start-ups. Spin-offs from companies are assigned to the original start-ups, provided the company from which the spin-off stems does not hold more than 50 percent of the shares in the new spin-off company A company closure is when a company no longer conducts any business activities and no longer offers products on the market. Cf. Bersch et al. (2020).

341 The MUP has a much narrower definition of economically active companies, market entries and market exits, so that relatively small entrepreneurial activities are not covered in the MUP.

342 In this regard and in the following, cf. Bersch et al. (2020).

343 In this regard and in the following, cf. Bersch et al. (2020).

344 In this regard and in the following, cf. Bersch et al. (2020).

C 6

345 Cf. Neuhäusler and Rothengatter (2020).

C 7

346 In addition to the indicators presented here based on the Web of Science bibliometric database, the indicators were also determined on the basis of the Scopus bibliometric database. Cf. Stephen et al. (2020).

C 8

347 This section and the following figures are based on Gehrke and Schiersch (2020).

348 For a methodical explanation of the RCA indicator, cf. Schiersch and Gehrke (2014: 74f.).

D 4

349 Cf. Gehrke et al. (2013).

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