5 Strategies and the policy mix for innovation

This chapter reviews public funding for innovation in Germany and presents the main innovation policy strategies and instruments. Germany has an extensive system of policy support for innovation, which was recently supplemented by the introduction of an R&D tax credit. While many public programmes are focussed on SMEs that already innovate, increasing attention is now being paid to raising the contribution of start-ups and previously non-innovation active firms. Guiding policy interventions is a well-developed, if at times fragmented, range of strategic documents, a growing number of which include mission-orientated principles.

Introduction

Germany's science, technology and innovation (STI) policy is well-resourced, with public expenditure on research and innovation (R&I) among the highest in the world. Relative to gross domestic product (GDP) in 2020, the latest year for which data are available, total government budget allocations for research and development (GBARD) were the fourth-highest in the world at 1.1%, behind only Japan (1.71%), Korea (1.25%) and Norway (1.15%) (OECD, 2022[1]). Still in 2020, German GBARD amounted to USD 50.3 billion PPP (US dollars at current USD purchasing power parity), trailing only the governments of the United States (USD 169.9 billion) and Japan (USD 90.9 billion). The volume of government expenditure on research and development (R&D), which is equivalent to 34.7% of total GBARD in the European Union that same year, illustrates the resources available to policy makers as they seek to promote and steer innovation.

Reflecting the federal system of government in Germany, public support for R&D is split between the federal and state governments through various mechanisms. A major component is project-based government financing, which accounted for 49.5% of GBARD in 2020. Many project-based initiatives are organised under the aegis of national strategies and programmes. These include thematic initiatives, such as the *Energiewende* ("Energy Transformation") and strategy for research and innovation, and the technology-specific programmes organised therein; and specific programmes targeted at small and medium-sized enterprise (SMEs), such as *Zentrales Innovationsprogramm Mittelstand* (ZIM), which emphasises increasing *Mittelstand* participation in innovative sectors. These approaches have supported a highly successful incrementalism in innovation, allowing German firms to remain at the technological frontier of many internationally competitive industries. Another example is *KMU-innovativ,* which has been running since 2007 to strengthen own research in SMEs and research co-operation with academia in key technologies, totalling more than 2 400 projects.

This section reviews the main national and thematic strategies, and the major direct and indirect public funding for R&D and innovation in Germany. It is structured as follows: Section 1 discusses Germany's major innovation policy strategies. Section 2 discusses direct and indirect public funding for R&D and innovation. Section 3 describes the policies under the "From the idea to market success" initiative.

5.1. Innovation policy strategies

Like many other countries, Germany is increasingly using national strategies to focus, promote and build on R&I efforts and promote the implementation of wider related changes. These strategies concern a range of thematic and technological areas. For example, the Federal Ministry for Economic Affairs and Climate Action (BMWK)-led *Energiewende* serves as Germany's national strategy for the sustainable energy transition and has a prominent innovation component (Table 5.1). In addition to high-level guiding strategies, Germany also has a range of other technology-specific initiatives in areas such as artificial intelligence (AI) and hydrogen, reflecting the importance of developing domestic competencies in emerging technologies to maintain international competitiveness as well as achieve transition-related objectives. Other strategies and programmes address specific technologies and topics, notably related to digitalisation, such as photonics, microelectronics, high-performance computing, information technology (IT) security and privacy, future communication technologies and materials, and civil security.

Some strategies fall under the responsibility of a single ministry, while others are cross-ministerial programmes. Typically, strategies are implemented through a mix of new and existing ministry-funded programmes, so that monitoring and evaluation of individual ministry strategies can easily be performed by building on existing evaluation routines. Cross-ministerial strategies are almost always led by a single ministry, but co-ordination between ministries is required for monitoring and evaluation. This has been a particular issue with the R&I strategy, where very little strategy-level evaluation effort was commissioned

until the current fourth edition. The High-Tech Strategy 2025 follows 12 missions, and the Fraunhofer Institute for Systems and Innovation Research has been commissioned to perform a real-time evaluation.

Table 5.1. Overview of selected national STI strategies and programmes

Strategy/programme	Start	Lead	Others	Co-ordination mechanism	Scope
Energiewende	2000	BMWK from 2014	4 ministries, Länder, federal agencies, industry, regulators	BMWK	R&I and implementation
Pact for Innovation	2005	BMBF, Länder	-	BMBF, Länder	PROs, DFG
Excellence Initiative	2005	BMBF	WR, DFG	DFG	Universities
High-Tech Strategy	2006	BMBF	All governmental departments	BMBF	R&I
Bioeconomy strategy	2010	BMBF	BMEL	BMBF	R&I
Industry 4.0	2013	BMBF, BMWK	Business, trade associations, Länder, tech transfer network, research council, FhG	Ministry/industry steering committee	R&I, implementation, dissemination
AI	2018	BMBF, BMWK, BMAS	Other ministries	BMBF	R&I
Quantum technologies	2018	BMBF, BMWK, BMVg, BMI		Co-ordination rounds between the ministries involved	R&D
Hydrogen	2020	BMWK	Other ministries	State Secretaries Committee on Hydrogen; National Hydrogen Council	R&I and implementation

Note: DFG = German Research Foundation; BMAS = Federal Ministry of Labour and Social Affairs; BMBF = Federal Ministry of Education and Research; BMI = Federal Ministry of the Interior and Community; BMVg = Federal Ministry of Defence; BMWK = Federal Ministry for Economic Affairs and Climate Action; WR = German Science Council.
Source: Various ministry websites

Many of Germany's key STI policy documents have a strong thematic focus on several areas that are important to the sustainability and digital transitions, even where they are not solely dedicated to these areas. This reflects in part a growing horizontality in German STI policy making, with key strategic documents intended to guide the STI system featuring high cross-referencing to previously disparate technology and knowledge domains. Similarly, many strategies that do focus on a particular technology area are also linked to socio-economic outcomes, such as inclusivity and resilience. For example, an analysis of strategy documents conducted by the OECD leads to a number of observations regarding how policy makers understand the role of different domains of STI in achieving specific socio-economic outcomes (Table 5.2).

Table 5.2. Priorities in Germany's STI policies (2018-22)

Sustainability	*Inclusivity*	*Resilience*	*Competitiveness*	*Digitalisation*
Sustainability is considered a **guiding principle for transitions**, particularly for innovation policy, with commitments to meeting sustainability objectives. Specific sectors, fields and technologies include: hydrogen • electric mobility/battery production • machine learning/AI.	Inclusivity in transitions focuses on **regional equality** as an important component for achieving STI policy goals in specific technology fields like **AI, automotive and other** industries, as well as in regional innovation hubs through bottom-up oriented innovation processes. Social inclusivity focuses on using digitalisation to reduce inequalities in education and public administration. At the same time, R&I policy seeks to strengthen regional innovation ecosystems to reduce inequalities Specific sectors, fields and technologies include: automotive and other industries and their regional suppliers • education • public administration.	Resilience goals during a transition relate to **securing value chains and enforcing disaster prevention**, as well as specific commitments to **strengthen the health care system**, increase the **attractiveness of health care jobs** and promote the **digitalisation** of the health care system. Specific sectors, fields and technologies include: • health care • global value chains • critical infrastructures • disaster prevention and civil defence • business continuity in essential areas.	Competitiveness focuses on improving **resource and energy efficiency**, supporting the **climate agenda** and using **digitalisation** to improve competitiveness in STI. Technological sovereignty is seen as a central pillar of future competitiveness. Commitments include developing **competence centres** and **regional hubs** in AI, quantum technology, hydrogen research, future communication technologies (6G) and cyber security. Specific sectors, fields and technologies include: • energy and climate • machine learning/AI • quantum technology • hydrogen • future communication technologies (6G) • cybersecurity.	Digitalisation is considered a crucial component of Germany's **competitiveness** and vital to addressing inclusivity issues. The government pledges to **digitalise** the **education and health care sectors.** Specific sectors, fields and technologies include: • education • health care.

Source: Einhoff, McGuire and Paunov (Forthcoming[2])

5.1.1. Strategy for research and innovation

One of the most important national strategic documents for STI is the strategy for R&I, which, currently in its fourth edition, is entitled "High-Tech-Strategy 2025" (BMBF, 2021[3]) – a new strategy entitled Future Strategy for Research and Innovation" (Zukunftsstrategie für Forschung und Innovation) is set to be published in the autumn of 2022. The R&I strategy is led and primarily funded by the Federal Ministry of Education and Research (BMBF) but involves co-ordination with and funding from all others, with several areas falling under the remit of BMWK. The R&I strategy has evolved considerably over the more than 15 years since it was established and is now one of the clearest expressions of "mission-oriented" policy in German STI.

The first R&I strategy, entitled "High-Tech Strategy" (HTS), was introduced in 2006 as an umbrella for the existing innovation policies from all departments of the German Federal Government that fund STI. The HTS aimed to provide an "all-of-a-piece R&I policy" by co-ordinating and orchestrating the programmes and policies of the Federal Government. This aim persists across all four releases of the R&I strategy published in each legislative period. The first R&I strategy was still technology-oriented, as it defined 17 technology fields of specific interest under the responsibilities and interests of several ministries. As these technology fields, as well as the policy programmes and actions, were in many ways a continuation of existing policies, observers and analysts criticised the HTS as being "old wine in new skins". Furthermore, no integration or intersection with innovation policies between the Federal Government and regional governments, or the European level is observed in the HTS.

From today's perspective, however, the R&I strategy has resulted in clear changes to innovation policy and measurable effects. In addition to the overall co-ordination effects across governmental departments and even within a few ministries, several new policy approaches and perspectives have been introduced. For example, additional co-ordination and integration at the lower level of individual policy programmes occurred in the aftermath of the HTS. For instance, earlier SME tools devised by the Ministry for Economic Affairs and Energy (now the Ministry for Economic Affairs and Climate Action, BMWK), like PRO-INNO, NEMO and INNOWATT, were integrated into the new ZIM programme, which became Germany's most important and effective SME programme and is still one of its largest innovation programmes, with an annual budget of over EUR 500 million. New policy approaches like the Leading-Edge Cluster Competition (renamed Clusters4Future in 2019) and the Excellence Initiative were established during this first edition of the R&I strategy. The HTS led to the Pact for Research and Innovation, which gives budgetary planning responsibility to non-university research organisations, who in exchange agree to co-ordinate better, collaborate more intensively and contribute to overarching policy objectives.

The HTS explicitly set overarching policy aims like the "3% goal" (i.e. spending 3% of GDP on R&D) and the 10% goal (spending 10% of GDP on science, technology and education). While the 10% goal's public visibility slowly deteriorated and it was not explicitly addressed in later periods, the 3% goal was continuously reached and during the 2018 edition of the HTS was increased to 3.5%. By the end of the first R&I strategy, the number of researchers in the German innovation system had increased by more than 100 000 – in public and private research labs – and the share of GDP spent on R&D had grown from 2.5% in 2006 to 2.9% in 2010, with stronger increasing public budgets in this first period of the HTS owing to the global financial crisis and the delayed leverage effect of public spending. The first R&I strategy definitely put STI higher on the agendas of policy makers and stakeholders, leading to higher visibility and higher budgets.

In 2010, the government adopted an updated and revised HTS. This version emphasised more strongly and concretely global and societal challenges as central to R&I policy and identified five such challenges: climate and energy, health and nutrition, mobility, security and communication (BMBF, 2021[3]). It also introduced the notion of directing R&I policy towards specific missions and suggested several "projects for the future" (*Zukunftsprojekte*), including "the CO^2-neutral, energy efficient and climate-adjusted city", "treating illnesses better with individualised medicine", "sustainable mobility" and "Industry 4.0" (BMWi,

2021[4]). Successors of the HTS were introduced in 2014 and 2018, providing the clearest case of mission-oriented policy approaches in Germany.

The analysis of the R&I strategy shows that Germany has been more ambitious than other countries with regard to identifying and propagating missions in key strategy documents (particularly the HTS 2025). However, experience with mission-orientated innovation policy is still limited, and it will be necessary to further explore how best to co-ordinate it in the context of strong ministries.

5.1.2. Pact for Research and Innovation

The Pact for Research and Innovation has run in five-year periods since 2005 (BMBF, 2022[5]). It is an agreement between the federal state (BMBF) and the *Länder* to provide stable and predictable institutional funding increases to the four major public research organisations (PROs) and the DFG. Its original aim is to increase enhance their strength and competitiveness, promote co-operation and co-ordination of research, develop the workforce, identify and enter new research areas, and improve links to the economy through collaboration with existing firms and spinning off new ones. In return, the organisations must meet specific policy-related performance targets:

- Pact I (2005-10) provided 3% per year nominal funding increases;
- Pact II (2011-15) had very similar goals, but offered budget growth of 5% per year;
- Pact III (2016-20) returned to 3% per year budget increases. It largely maintained the existing goals, but added a requirement to make internal procedures more family-friendly and to include a minimum of 30% of women in the beneficiary organisations' senior committees;
- Pact IV (2021-30) runs for ten years, but is subject to review after five. It provides budget increases of 3% per year and hones – rather than changes – most of the existing goals.

Excellence Initiative

The Excellence Initiative was launched in 2005 to create a subset of elite universities capable of competing internationally with global leaders (DFG, 2022[6]). It provided EUR 4.6 billion in additional research funding to higher education institutions (HEIs) from 2006 to 2017 (i.e. about EUR 420 million per year). In parallel, the (teaching-oriented) Higher Education Pact resulted in additional funding of EUR 4.5 billion from 2007 to 2020 (i.e. about EUR 320 million per year).

The Excellence Initiative emerged from a period starting in the 1990s where the performance of German universities was increasingly seen as average (Möller, 2018[7]) and a desire emerged to pursue something more akin to the model of prestigious "excellent" research universities that tended to reach the top of the international university rankings. Like other European countries, Germany adopted this approach to have strong research universities across all the regions with the aim of providing strong, locally accessible higher education for all.

The initiative underwent its first two rounds in 2005/06 and a further round in 2012. The formal aims of the initiative were to:

- support high-quality research in the interest of the economy
- mobilise and retain excellent researchers in the universities and German industry
- support cutting-edge interdisciplinary research to address demographic changes and international competitiveness
- improve the rankings of the best German universities in the face of the strong Anglo-American challenge and the rapid development of high-performing universities in Asia.

The Excellence Initiative was run by the DFG and the Science Council (*Wissenschaftsrat)* on behalf of BMBF. It established 40 graduate schools and funded 30 Clusters of Excellence; universities that won grants in both categories were awarded further development funding and labelled "Excellence Universities" (DFG, 2019[8]). Much of the initiative's funding went to strong existing universities, especially in Southern Germany. In a context where all universities have been increasing their research productivity (in terms of publications per professor) and number of citations per paper, the effects of the initiative are not clearly discernible. While the productivity differential between Excellence and other universities remained substantial between 2004 and 2011, the citation rates of the non-Excellence universities have caught up with those of the Excellence Universities (Stockinger, 2018[9]). The initiative was replaced by the Excellence Strategy in 2019, which no longer funds graduate schools, but only Excellence Universities and Clusters of Excellence (BMBF, 2019[10]).

The Excellence Initiative appears to have hastened the rate at which beneficiary universities were able to increase their total research expenditure, and the likelihood of winning competitive research funding between 2003 and 2012 was much greater for the beneficiaries than the non-beneficiary universities (Möller, 2018[7]). Bibliometric analysis suggests that the effect of the initiative was to concentrate more highly cited work among the beneficiary universities, but that there was no increase in performance at the level of the German university system as a whole (Möller, Schmidt and Hornbostel, 2016[11]).

5.1.3. Other thematic innovation policy strategies

AI Strategy

The government adopted the National AI Strategy in 2018 and updated it in 2020 (BReg, 2020[12]). The strategy was the result of a nationwide online consultation, expert fora with research and industry, and a short series of consulting studies examining the opportunities in Germany and comparing AI strategies in other countries. The rationale for the strategy was that while Germany had a fairly strong position in AI research, there existed a need to respond to the huge investments being made abroad in AI research and application, especially in light of the sluggish adoption rate in Germany. The strategy is driven by BMBF, BMWK and BMAS, but other ministries also participate in niches, typically related to their sector as a potential adopter of AI.

The AI Strategy focuses on the development of "weak AI", in the sense of systems that are essentially supportive, as opposed to systems that aim to achieve levels of intelligent behaviours that imitate or rival human capabilities. This implies a focus on applied R&D rather than fundamental research, with the aim of using AI to support or establish competitive industrial positions. The strategy has three main goals:

- make Germany (and Europe) a leading centre for AI, thereby helping to safeguard Germany's competitiveness;
- promote responsible development and use of AI that serves the good of society;
- integrate AI in society within ethical, legal, cultural and institutional structures, in the context of a broad societal dialogue and active political measures.

The strategy involves 12 fields of action with specific interventions. These include increasing funding for research and research transfer; expanding bi- and multilateral research collaboration; building up competence centres, application hubs, clusters, testbeds and AI observatories; providing AI-specific SME support, start-up funding and venture capital; improving the data architecture; strengthening AI training and skills; updating guidelines for the use of AI; disseminating information about AI applications in society; and establishing a social dialogue about AI. Funding was originally set at EUR 3 billion and subsequently raised to EUR 5 billion after publication of a progress report on the strategy.

The strategy goes beyond traditional "key technology" programmes in establishing a strong ethical and social responsibility dimension, as well as the early involvement of regulators. Until recently, however, it

had no specific and measurable goals. It also involves other stakeholders and the general public only to a limited extent, and is not as strongly connected to demand-side measures or clear about the role of citizens. It is therefore a rather traditional – though wide-ranging and well thought-out R&I strategy that essentially assumes AI will be a ”plug-in” technology within the existing sociotechnical regime.

The energy transformation (Energiewende) and the national hydrogen and bioeconomy strategies

BMWK leads a major national and multidisciplinary strategy, *Energiewende,* targeting the energy aspects of the sustainability transition. Given the importance of developing and commercialising technologies that can both support the decarbonisation of the German economy and underpin the future competitiveness the country’s private sector in this decarbonised context, *Energiewende* has significant overlaps with STI policy (European Commission, 2018[13]). Organised jointly under BMBF and the Ministry for Food and Agriculture (BMEL), the 2020 German National Bioeconomy Strategy aims to maximise the potential of the bioeconomy for Germany and strengthen the country’s role as a bioeconomy leader (BMBF/BMEL, 2020[14]). A cross-ministerial National Hydrogen Strategy was published in 2020 (BMWi, 2020[15]). Chapter 11 describes these strategies in more detail.

Strategic initiatives in the field of quantum computing

In line with the framework programme “Quantum Technologies – from basic research to market” launched in 2018, the Federal Government is providing EUR 650 million for research into quantum technologies between 2018 and 2022 (BMBF, 2020[16]). In early 2020, the government also announced it was earmarking an additional EUR 300 million for this technology. Finally, the Federal Government's economic stimulus and future package, adopted in mid-2020, pegged an additional EUR 2 billion for quantum technology, including around EUR 1.1 billion allocated to BMBF funding for this research area.

Along these lines, BMBF is funding the development of quantum computer hardware, i.e. quantum computer demonstrators in Germany, within the related call published in 2021 (“Quantum Processors and Technologies for Quantum Computers”). The goal is to fund research on competitive German quantum computers with at least 100 individually controllable quantum bits (qubits) within 5 years, scalable to at least 500 qubits. The most promising technological approaches are being pursued to this end. The systems are based on domestic or European research results and made comprehensively accessible to users, for example through appropriate connection to a cloud. The work is intended to lay the foundation for an error-corrected system to be available in 10 to 15 years that will allow solving a universal class of problems, thereby achieving a broad benefit for the economy and society. Companies in the commercial sector, as well as universities and non-university research institutions, are involved in the funded projects.

These measures are accompanied by the BMBF call "Application Network for Quantum Computing", which funds projects that develop quantum algorithms and software to explore the potential of quantum computing in different application areas, such as energy networks or industrial manufacturing.

5.2. Direct and indirect public funding of R&D and innovation in Germany

Although the business sector is the single largest source of R&D financing in Germany, the government – at both the federal and regional levels – retains an important role in R&I funding. In many ways, the government’s funding instruments and approaches – whether it be providing institutional funding for basic research, creating targeted funding programmes for certain actors or technologies, or providing indirect funding through the newly created R&D tax credit – are the most powerful levers available to it to shape and direct the country’s innovation system.

5.2.1. Federal and state responsibilities in R&D and innovation

The policy mix in Germany is influenced by the division of responsibilities between the federal and *Länder* levels, and funding programmes are generally directed at the country's manufacturing sector rather than service-based firms. The federal level pays most of the cost of government activities in R&I. However, few programmes fund innovation-related activities other than R&D, and these programmes are themselves relatively small. In practice, innovation policy is mostly made at the level of the *Länder*, which tend to have and execute their own innovation strategies based on their individual characteristics. This also provides opportunities to direct large amounts of European structural funds in the poorer *Länder* at innovation, while taking advantage of the richer *Länder*'s ability to pay for innovation policy in their own territories. The combined effect is to focus the federal policy mix on formal R&D and technology transfer, as opposed to the later stages of the innovation process. The dominant instrument is direct funding of R&D, in the guise of collaborative grants to consortia bringing together actors from public research and industry.

5.2.2. Federal government financing of R&D

The Federal Government finances R&D through a variety of funding mechanisms and federal ministries; the largest contributions are made by BMBF (54.3% of total federal R&D financing in 2019) and BMWK (17.7% of total federal R&D financing in 2020) (BMBF, 2021[17]).

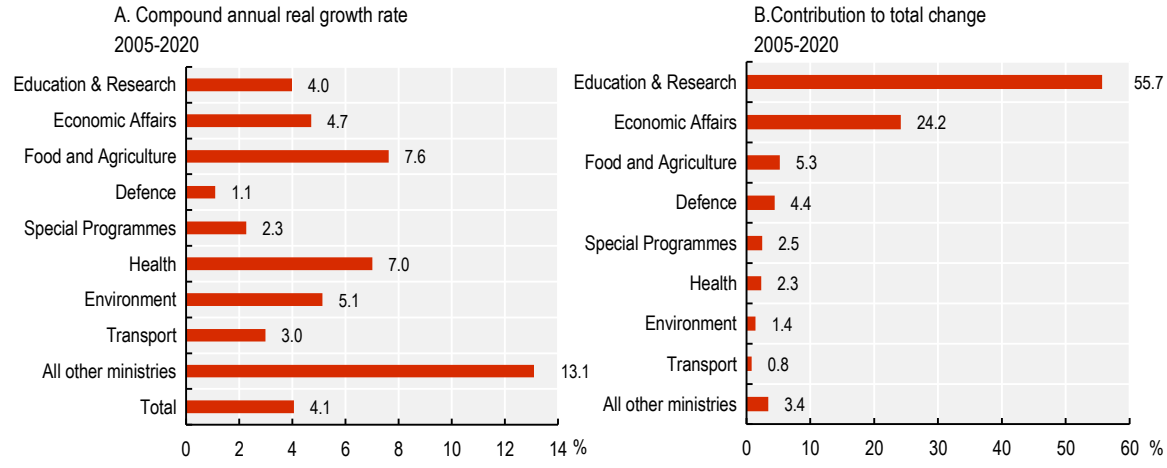
Most of the Federal Government's institutional funding of PROs and research-funding agencies (such as the DFG, which accounts for 45% of total federal R&D financing) is distributed through the BMBF budget. A further priority of R&D financing by BMBF is project-based funding within thematic programmes such as health; environment, climate and sustainability; microelectronics; high-performance computing; information and communication technology (ICT), including future communication technologies; cybersecurity; nanotechnology and new materials; bioeconomy; production technology; photonics; quantum technologies; civil security; and education, humanities and social sciences.

BMWK, for its part, finances R&D mainly through project-based programmes, including ZIM and some thematic research programmes (on energy, aviation and space technologies, transport technologies and some areas of ICT). In 2019, BMVg contributed 7% to total federal R&D financing, mainly by funding large defence R&D projects (including procurement). BMEL runs the fourth-largest R&D budget (3.6% in 2019) within the Federal Government. All other federal ministries contributed 5.3% of total federal R&D financing in 2019; 3.0% of the federal R&D budget is for special programmes that are not allocated to one of the federal ministries. In 2019, this mainly applied to the "Energy and Climate Funds", which provides R&D financing for certain federal initiatives, including the E-Mobility initiative.

As Figure 5.1 shows, the substantial increase in federal R&D financing from 2005 to 2020, amounting to a +4.1% compound annual real growth rate (CARGR), was distributed unevenly across federal ministries: 55.7% of the increase was allocated to BMBF's budget (+4.0% CARGR), and 24.2% to BMWK (+4.7% CARGR). Above-average growth rates in R&D financing are reported for the federal ministries of food and agriculture (+7.6%), health (+7.0%) and environment (+5.1%), as well as for all ministries with low absolute R&D financing (+13.1%). Below-average growth reports were reported for the federal ministries of transport (+3.0%) and defence (+1.1%), as well as for non-ministerial special programmes (+2.3%).

Figure 5.1. Change in federal R&D financing, by federal ministry (2005 to 2020)

Compound annual real growth rate (CAGRG) (LH) and contribution to total change (RH)



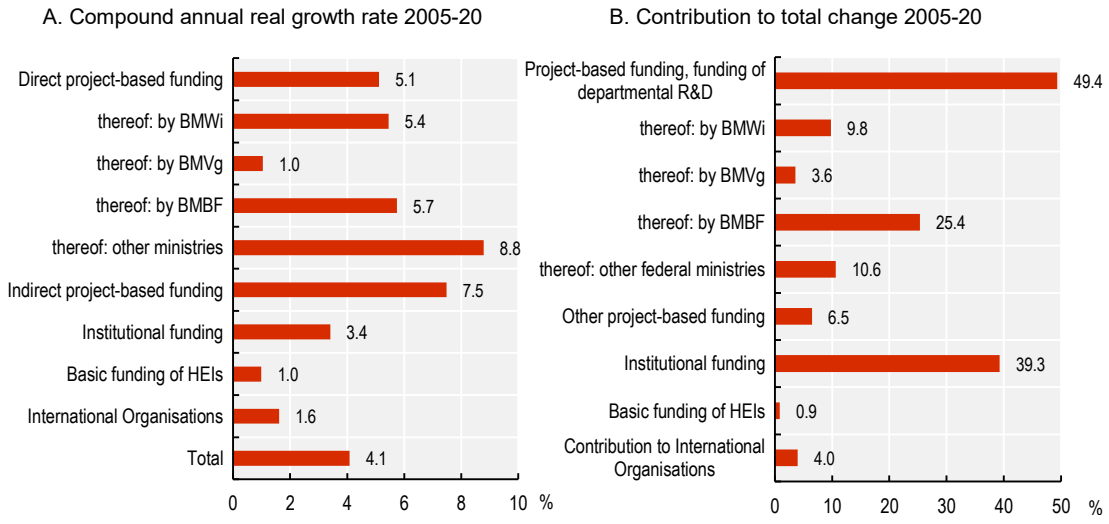
Note: LH = left hand. RH = right hand.
Source: BMBF (2022[18]), Federal Government expenditure on science, research and development, by departments (database), Federal Ministry for Education and Research (BMBF), https://www.datenportal.bmbf.de/portal/en/K1.html (accessed on 1 March 2022).

The Federal Government distributes R&D financing through two main channels: project-based funding for R&D projects (either targeting the development of specific technologies, labelled “direct” funding in many government documents, or targeting the diffusion of technologies, labelled “indirect” funding) and institutional funding of PROs (including the DFG). Project-based funding (including contract research) accounted for 49.5% of total federal R&D financing in 2020. Institutional funding represented 44.5% (including special federal funding programmes for HEIs, mainly for buildings and other fixed investment). The remaining share (6.1%) went to international organisations and international R&D programmes.

Between 2005 and 2020, 55% of the increase in federal R&D financing was distributed through project-based funding and 40% through institutional funding, implying a slight shift towards project-based funding. This is also reflected in the higher CARGR of project-based over institutional funding (Figure 5.2).

Figure 5.2. Change in federal R&D financing, by main instruments (2005 to 2020)

CARGR (LH) and contribution to total change (RH)



Note: LH = left hand; RH = right hand

Source: BMBF (2022[19]) Federal Government expenditure on science, research and development, by types of funding, Federal Ministry for Education and Research (BMBF), https://www.datenportal.bmbf.de/portal/en/K1.html (accessed on 20 April 2022).

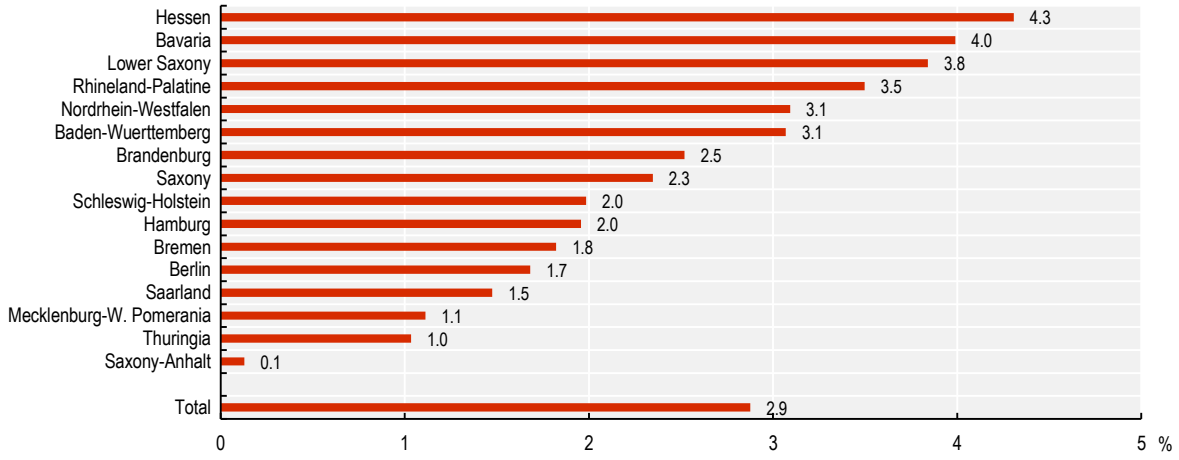
Federal R&D financing targets different groups of recipients. In 2019, 50.1% of total R&D financing went to PROs (including government agencies), 10.7% to HEIs, 12.6% to the DFG (mainly allocated to HEIs), 18.3% to businesses (including a very small share of business located outside Germany) and 8.3% to international organisations. These relationships did not change significantly between 2005 and 2020, although some shifts can be seen. R&D financing for HEIs and the DFG grew markedly faster (respectively by +5.8 and +6.8%), signalling the stronger engagement of the Federal Government in funding university research as part of the "Excellence Initiative". PROs reported a CARGR of 3.5%, slightly below the average CARGR of federal R&D financing (+3.9%). R&D financing for business enterprises (+3.1%), and for international organisations and programmes and other recipients abroad (+2.6%), expanded more slowly.

5.2.3. Regional government financing of R&D

From 2005 to 2017, R&D financing by regional governments grew by 2.9% (CARGR), but this increase was shared unequally across the 16 *Länder* (Figure 5.3). Several regions with strong manufacturing bases, including Hessen, Bavaria, Lower Saxony, Rhineland-Palatinate, North Rhine-Westphalia and Baden-Wuerttemberg, experienced above-average growth rates. At the same time, city-states (Hamburg, Bremen and Berlin) and all five states in Eastern Germany (Brandenburg, Saxony-Anhalt, Mecklenburg-Western Pomerania, Thuringia and Saxony) saw below-average increases in R&D financing.

Figure 5.3. Change in R&D financing of German Länder, by state (2005 to 2017)

Compound annual real growth rate (%)



Source: BMBF (2022[20]), Regional distribution of R&D expenditure in the Federal Republic of Germany (implementation) and of government R&D expenditure by the Länder (financing), Federal Ministry for Education and Research (BMBF), https://www.datenportal.bmbf.de/portal/en/K1.html (accessed 1 March 2022)

The total increase in R&D financing by states from 2005 to 2017 (roughly EUR 5 billion) was mainly driven by just five *Länder* – North Rhine-Westphalia, Bavaria, Baden-Wuerttemberg, Lower Saxony and Hessen – which together contributed 75% (Figure 5.4). Their contribution in 2017 was significantly higher than at the beginning of the expansion period in 2005 (63%). This means that the expanded R&D by state governments strengthened the position of large western states with a strong innovation system. Both in 2005 and 2017, the share of these five states in total R&D performance (by business enterprises, HEIs and PROs) in Germany amounted to 78%, mainly driven by business expenditure as most of the large R&D-intensive corporations are located in these states.

Figure 5.4. Contribution to total change in R&D financing of German Länder, by state (2005 to 2017)

Source: BMBF (2022[20]), Regional distribution of R&D expenditure in the Federal Republic of Germany (implementation) and of government R&D expenditure by the Länder (financing), Federal Ministry for Education and Research (BMBF), https://www.datenportal.bmbf.de/portal/en/K1.html (accessed 1 March 2022).

The different dynamics of R&D financing by state governments stem from two main factors. First, the fiscal scope of governments is strongly linked to industry structure, GDP per capita and the costs of local social security expenditure. In this respect, large western states have a higher flexibility in providing additional funding for R&D than eastern states or city-states. Second, R&D financing by state governments is closely tied to funding HEIs and PROs. The expansion of R&D in the German science system since 2006 is closely linked to the Excellence Initiative and the Pact for Research and Innovation, both of which are based on bipartisan (federal and state) financing schemes. Hence, state governments with a strong science system are better positioned to attract additional federal funding to further strengthen their HEIs and PROs, either by expanding institutional financing or offering additional project-based funding (such as through the Hessian government's Loewe Programme).

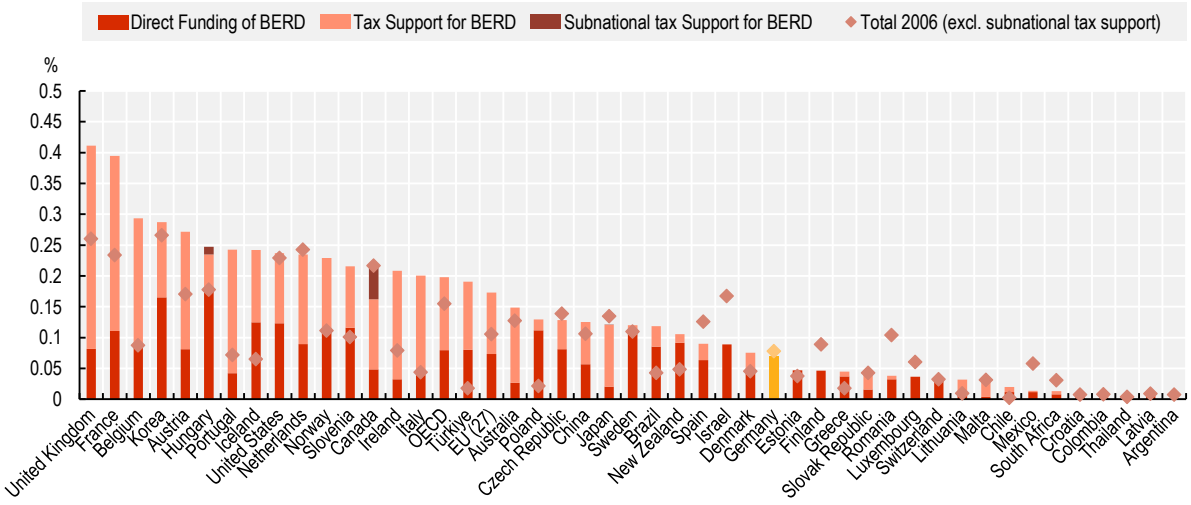
It is important to know that R&D financing is one (of many) mechanisms used to compensate for lower competitiveness of eastern and western states with structural problems (e.g. Saarland, Bremen and Berlin). Financing of the large HEI and PRO sector in these *Länder* serves to increase the regions' attractiveness for private investment, by offering a sufficient supply of a well-educated workforce and a knowledge infrastructure for co-operation among firms. Thus, eastern states as well as Berlin, Bremen and Saarland have the highest state R&D financing per GDP. At the same time, providing equal living conditions as much as possible across all regions of Germany has been a priority, in accordance with the respective article in the German constitution. Funding public science in all regions is a key element in this respect. Consequently, per capita R&D financing by state governments does not differ substantially across states, except for city-states (showing higher figures) and states close to major metropolitan areas (such as Brandenburg and Schleswig-Holstein) showing lower figures, as they are supplied by science institutions in the metropolitan areas (such as Berlin and Hamburg).

5.2.4. Indirect financing of innovation: R&D tax credit

In 2020, Germany introduced an R&D tax credit aiming to create incentives for firms (particularly SMEs) to increase their research expenditure. Expenditure-based R&D tax incentives are common across the OECD region to help address R&D market failures: they accounted for around 55% of total government support for business R&D in the OECD in 2017, up from 30% in 2000 (OECD, 2021[21]). In 2020, Germany introduced such a policy instrument for the first time, with the tax incentive subsidising business expenditure on R&D (BERD) of up to EUR 2 million each year (Figure 5.5). As part of the COVID-19 recovery package, the cap was increased to EUR 4 million per firm until the end of 2025, whereupon it will revert to the lower level. The incentive, known as the "Research allowance", allows firms to claim 25% of total in-house R&D personnel costs and up to 60% of extramural R&D costs for R&D contracts performed by contractors located in the European Economic Area.

Figure 5.5. Direct government funding and government tax support for business R&D (2019 and 2006)

As a percentage of GDP



Source: OECD (2021[21]), *OECD R&D Tax Incentives Database,* http://oe.cd/rdtax, April 2022.

The tax credit is a welcome addition to the policy instruments available to support STI in Germany. Similarly – and reflecting in part broader challenges with bureaucracy – several firms participating in focus groups for this review noted that the process of applying for the R&D tax credit was cumbersome, which could dissuade smaller firms with lower levels of internal administrative capacity.

5.2.5. Funding for thematic programmes

Germany has allocated significant funding for particular technology domains of current and future importance for success in the sustainability and digital transitions. These programmes cover a wide range, including electronics and microelectronics, high-performance computing, advanced ICT (including future communication technologies), cybersecurity, aviation and space technologies, materials, maritime technologies, nanotechnologies, quantum technologies, optical technologies and photonics, production and service technologies, and civil security. Many of these funding programmes have strong industry linkages. Responsibilities and budgets are divided between the two ministries. BMBF runs programmes for strategic, application-oriented basic research (technological-readiness levels 1 to 3) related to health, sustainability, climate protection and energy, mobility, urban and rural development, security, and economy and Work 4.0. BMWK runs applied R&D activities to help commercialise research, for example on industrial biotechnology and lightweight construction. Some other programmes start as thematically open competitions and become thematically focused during the execution phase. Section 5.3 describes funding arrangements for several key programmes.

5.2.6. Programmes with an international perspective

In addition to national participation in the EU framework programme, Eureka and various multilateral research organisations, such as the European Organization for Nuclear Research and the European Molecular Biology Laboratory, both BMBF and BMWK run programmes to help German research performers develop internationalisation strategies and companies establish small R&D partnerships. In 2017, BMBF updated its "Strategy on Internationalisation of Education, Science and Research" (2008) to reflect growing trends and challenges (such as digitalisation). The strategy focuses on global co-operation,

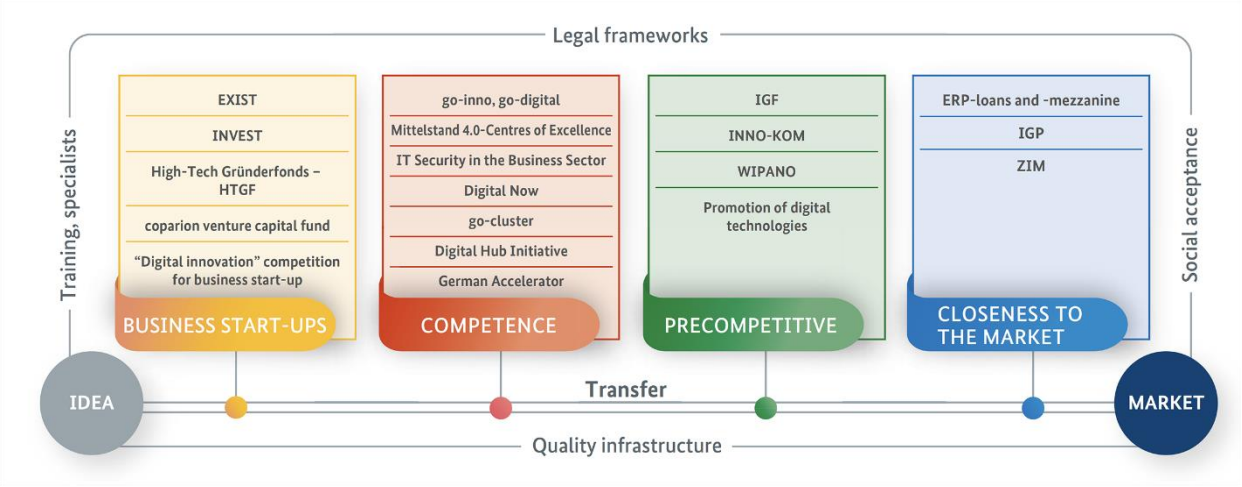
developing the European Research Area, international business networking (especially for SMEs), and co-operation on vocational training with emerging or developing countries. The associated funding programme supports both academic institutions and SMEs (BMBF, 2022[22]). BMWK programmes also have specific funding portfolios for international co-operation. For example, the *Existenzgründungen aus der Wissenschaft* ('Start-ups from science') (EXIST)-Potentiale competition awards funds to universities and clusters to support the internationalisation of start-ups. Also, the ZIM programme provides specific funding for international innovation and cooperative R&D networks (BMWK, 2022[23]; BMWi, 2017[24]).

5.3. "From the idea to market success" and related programmes

Many BMWK programmes that support applied R&D are organised under an umbrella initiative, called "From the idea to market success" (BMWi, 2020[25]) Reflecting the importance of the *Mittelstand* to Germany's innovation system and, more broadly, to the country's economic competitiveness, BMWK has an expansive set of policy instruments to support SME innovation.

The "From the idea to market success" programme for an innovative SME sector comprises the major innovation policy instruments of the BMWK (Figure 5.6). Each of its four programme families targets specific challenges facing firms during the innovation process: early product development and funding ("Business start-ups"); competence development ("Competence"); precompetitive aspects of technology transfer ("Precompetitive"); and barriers during market entry ("Closeness to the market"). In addition to direct assistance, the overarching programme aims to promote an innovation-friendly ecosystem, public acceptance of innovation processes, and a functional and high-quality infrastructure.

Figure 5.6. From the idea to market success: Institutions and policies



Source: BMWi (2020[25]).

5.3.1. Business start-up programmes

The first programme family, "Business start-ups", aims to support start-ups in the early phases of the innovation process, especially by remedying the lack of funding for precommercial innovations and business ideas. This includes supporting innovative start-ups through a policy package combining R&D-related measures, financing, stimulating start-ups at HEIs, and consultancy and information services. Three of the main instruments to this end are the EXIST, INVEST and High-Tech Gründerfonds (HTGF) programmes.

Science-based start-ups – Existenzgründungen aus der Wissenschaft (EXIST)

Since the late 1990s, entrepreneurship and spin-off activities at higher education and non-university research organisations have been supported by the EXIST programme, under the auspices of BMWK. EXIST is one of the longest-running innovation programmes (BMWK, 2022[26]). It aims to improve the entrepreneurial culture and environment at universities and research organisations, which at the time was rather underdeveloped but has since improved. The programme helps students, graduates and scientists prepare technology-oriented and knowledge-based start-ups. Starting from five model regions, EXIST has expanded through several phases, substantially supporting the slow but steady rollout of entrepreneurship education across the German university system over the past two decades. The programme offers start-up scholarships to aspiring entrepreneurs of up to EUR 3 000 per month and covers material expenses up to EUR 30 000. In addition, it provides up to EUR 250 000 to participating high-tech start-ups in the funding phase and up to EUR 180 000 after the company is founded. Universities can also receive funding for project-related expenses of up to EUR 100 000 during the early concept phase (six months) and up to EUR 2 million during the following project phase (up to four years).

Zuschuss für Wagniskapital (INVEST)

Since 2013, INVEST has supported young innovative companies seeking venture capital (VC) funding, as well as private investors aspiring to become business angels (BAFA, 2022[27]). The programme has provided more than EUR 900 million in risk capital since its inception. It promotes investments in innovative start-ups through an acquisition grant of up to EUR 500 000 per year; once investors sell their shares, it provides an exit grant. INVEST's acquisition grant can support total investments per company of up to EUR 3 million per year. The tax due on a capital gain can be compensated as a lump sum with an exit grant.

High-Tech Gründerfonds (HTGF)

With the HTGF, the Federal Government set up a powerful platform-based support structure for start-ups – which, while not primarily science-oriented, can be leveraged to support the best and most relevant ideas from science as well (HTGF, 2022[28]). Arguably, the HTGF is the central vehicle of federal support for high-potential innovative start-ups. As a platform with its own investment managers, it combines funding from different public and private sources. Since its establishment in 2005, the HTGF has supported more than 600 investments, and had more than 150 successful exits and initial public offerings, and manages a portfolio of nearly EUR 900 million. In addition to providing capital, the fund provides the necessary support for the management of young start-ups: it extends initial funding of up to EUR 1 million, with a total of up to EUR 3 million usually available per company. In its first phase (up to November 2011), the fund extended a total of EUR 272 million in financing. The follow-up fund (HTGF II) provided EUR 304 million. A third fund, HTGF III, was launched in the third quarter of 2017, with a EUR 319.5 million financing envelope. In addition to support from BMWK and the KfW Capital, 33 private investors – either well-established SMEs or large corporations – have contributed more than 30% of the amount. To be eligible for financing, projects must have shown promising research findings based on innovative technology, and the market situation for the product must be promising. Further support programmes exist under the management of KfW and various local development banks, but their threshold for support is generally much lower. A new generation of the Fund (HTGF IV) with an investment volume of more than EUR 400 million was announced in June 2022 (BMWK, 2022[29]).

Other support measures in the "Business start-up" programme family

Three further initiatives complete this first programme pillar. The EUR 275 million **coparion VC fund** is financed by the European Recovery Programme (ERP) Special Fund, KfW Capital and the European Investment Bank (coparion, 2022[30]). Jointly with private investors, the fund invests in equity capital to

support start-ups and SMEs under ten years old that are developing innovative products, processes or services. Via the **ERP Venture Capital Fund Investment programme**, also financed by the ERP Special Fund, KfW Capital can invest a maximum of 19.99% or EUR 25 million in German and European VC and VD funds. A total of EUR 180 million p.a. is available through this programme to strengthen the VC and start-up landscape. The "**Start-up Competition for Digital Innovations"**, held every six months since 2021, aims to attract innovative start-ups in the field of ICT. In each round, up to six start-up ideas will each be awarded EUR 32 000 in seed capital, and up to 15 further ideas will be awarded cash prizes of EUR 7 000. In addition, a special prize of EUR 10 000, thematically based on the Federal Government's Digital Agenda, is awarded during each round of the competition.

5.3.2. Competence programmes

The second programme family, "Competence", provides direct funding and consulting services to firms to improve their (digital) competencies, and also supports innovative clusters and firms, both regionally and abroad. The "go"-programmes and the *Mittelstand 4.0* Centres for Excellence are two of the main instruments in this second family.

Go-inno and go-digital

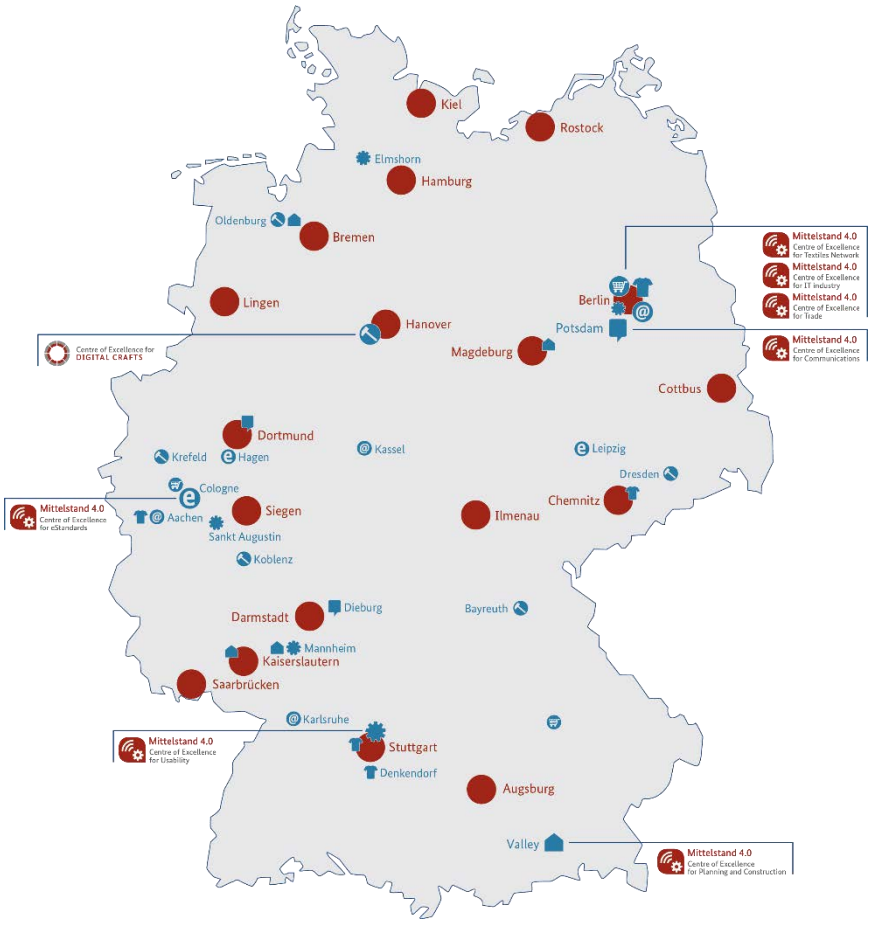
The "go-inno" and "go-digital" programmes fund external management and consulting services related to product and technical process innovations, and digital business processes (BMWK, 2022[31]). Go-inno specifically targets the preparation and implementation of product and technical process innovations, without thematic restrictions to specific technologies, products, sectors or branches of industry. The go-digital programme aims to provide the beneficiary company with expert advice by authorised consulting firms to support the implementation of necessary measures related to digitisation strategy, IT security, digitised business processes, data competence and digital market development. Go-digital and go-inno cover 50% of external consulting services expenses, up to EUR 1 100 per consultancy day.

Mittelstand 4.0 Kompetenzzentren (competence centres)

Since 2015, BMWK has established a total of 26 *Mittelstand 4.0* competence centres as part of the funding announcement "*Mittelstand 4.0*", which are located throughout Germany (Figure 5.7) (BMWi, 2020[32]). These centres act as regional and topic-related contact points for SMEs, and have significantly raised awareness among SMEs of the opportunities and challenges of digitisation. *Mittelstand 4.0* competence centres offer neutral, cost-free information, demonstration, qualification and accompaniment, including workshops, visits of demonstration plants, meetings with experts and practical support for SMEs developing their own digital solution. The *Mittelstand 4.0* competence centres are separate consortia of universities, Fraunhofer institutes and other external partners (like chambers of commerce). Within these consortia, each partner takes on a specific role tied to its area of competence (e.g. 3D printing, flexible manufacturing or new business models). All partners act together to promote the overarching topic of digital transformation. The internal evaluation reports from the *Mittelstand 4.0* competence centres show many positive effects emanating from the centres. SMEs who were involved in concrete development projects with the centres particularly benefitted from the support of the affiliated experts.

The way in which the measure was able to reach SMEs and organise support for their digital projects can be called a success story, especially for SMEs who had at least a basic interest in or affinity with digital technologies. Arguably, the *Mittelstand 4.0* competence centres contribute substantially to speeding up the integration of digital technologies in SMEs (BMWi, 2019[33]). However, as noted in the ministry's report, a more general assessment of the impacts of this measure is methodologically challenging because in addition to the competence centres, several other institutions (e.g. business associations, chambers of commerce and software suppliers) also support the digital transformation efforts of SMEs.

Figure 5.7. Location of Mittelstand 4.0 competence centres (2020)



Note: Red dots indicate the location of 4.0 Competence Centres. Blue dots denote contact points for cross-cutting topics.
Source: BMWi (2020[32]), Förderschwerpunkt Mittelstand-Digital: Die Mittelstand 4.0-Kompetenzzentren, https://www.mittelstand-digital.de/MD/Redaktion/DE/Publikationen/Factsheets/faktenblatt-mittelstand4.0.pdf?__blob=publicationFile&v=5 (accessed 1 March 2022).

Germany is not the only OECD country experimenting with new facilities for demonstrating and testing new technologies. Similar to the German competence centres, Norway's "Catapult Centres" aim to enhance digital technology adoption and diffusion. Similar initiatives from other countries include financial support for digital technology investments and other support services (e.g. the "SMEs Programme for Smart Manufacturing" in Korea and "service design vouchers for manufacturing SMEs" in the Netherlands) and improving access to state-of-the-art facilities and expertise (e.g. through high-performance computing centres in many European countries) (Planes-Satorra and Paunov, 2019[34]).

Other support measures in the "Competence" programme family

The second programme family, "Competence", features a range of other initiatives. **"IT Security in Business"** was initiated in 2011 by BMWK in co-operation with the business community to improve awareness of IT security among SMEs. The initiative primarily supports SMEs with concrete measures and expert assistance to improve their IT security when using ICT systems and implement basic IT security measures. It also aims to facilitate the transfer of knowledge and technology to SMEs, create awareness of IT security, and promote networking with multipliers and other initiatives. A transfer office is accessible through a virtual and mobile (tour bus), as well as through 80 regional showcases at trade association offices (BMWi, 2019[35]).

"**Digital Now – Investment Support for SMEs**" aims to encourage SMEs to invest in digital technologies and know-how across industries and regions in order to strengthen their competitiveness and innovative capacity (BMWi, 2020[25]). The programme funding is structured around two modules. The first covers investments in digital technologies and related processes and implementations, such as data-driven business models, AI, cloud applications, big data, IT security and data protection. The second finances investments in employee qualification measures related to digital technologies, including qualifications or further training in digital transformation, digital strategy, digital technologies, IT security and data protection, digital and agile working, and basic digital skills.

"**Go-cluster"** supports regional innovation clusters in their efforts to build networks and promote exchange with other national and international clusters (BMWi, 2020[25]). The programme offers project-funding grants of up 50% of the total eligible expenditure or a maximum of EUR 100 000 per project across three funding priorities, as follows: 1) support clusters seeking to develop and pilot new concepts for strategic innovation and foresight management; 2) support clusters seeking to identify and develop new fields of action and turn them into a business or revenue model; and 3) provide open-topic funding for the development and piloting of new cluster services without thematic predefinition, as well as cross-cluster project co-operation.

The **Digital Hub Initiative** supports the establishment of digital hubs across Germany connecting German and international start-ups with established companies, researchers and investors in a specific region, following the example of Silicon Valley (BMWi, 2020[25]). The hubs aim to promote networking and co-operation within and between hubs, and are expected to serve as platforms for dialogue with global market leaders and foreign investors. To facilitate such interactions, the initiative developed a joint brand ("*de:hub*") and created a joint "Hub Agency". Efforts are ongoing to develop an international marketing campaign to build the hubs' reputation abroad and attract international start-ups, scientists, companies and investors. Hubs currently exist in 12 cities, each focusing on a particular industry (e.g. the IoT&Fintech hub in Berlin, the Digital Hub in Karlsruhe focusing on AI, and the Digital Chemistry and Digital Health hub in Ludwigshafen/Mannheim) (Planes-Satorra and Paunov, 2019[34]).

The **German Accelerator** was created in 2012 to support German start-ups in their international expansion, with locations in San Francisco, New York, Boston and Singapore, and a number of business angels and mentors (BMWi, 2020[25]). Participating firms receive free office space and access to a global network of partners and investors. More than 240 start-ups have successfully participated in the programme since its launch, receiving funding totalling more than USD 3 billion. The German Accelerator is managed by German Entrepreneurship GmbH and supported by the BMWK.

5.3.3. Precompetitive programmes

The third programme family, "Precompetitive", supports joint R&D projects of SMEs and industrial research institutes as well as the commercialisation of research results. Its most important programmes are "*Industrielle Gemeinschaftsforschung*" (IGF), "INNO-KOM" and "WIPANO – Knowledge and Technology Transfer through Patents and Standards".

Industrielle Gemeinschaftsforschung (IGF)

In 2020, IGF provided EUR 201 million for R&D projects performed by member organisations' research institutes (30% in 2020), HEIs (55%) and PROs (15%), for (mostly co-operative) projects (BMWi, 2020[25]). SMEs do not directly receive funding within such projects but are involved in the definition of R&D projects and can use the project results. In 2020, the German Federation of Industrial Research Associations (AiF) reported that almost 25 000 SMEs were involved in the 1 876 projects funded by IGF in 2020, amounting to about 13 SMEs per project. A subsidiary company of the AiF also serves as a programme agency for the ZIM programme (co-operative projects only).

INNO-KOM

INNO-KOM supports non-profit industrial R&D institutes in eastern – and since 2017, western – Germany regions with structural problems, as defined by the constitutional Joint Task "Improvement of the regional economic structure" (Gemeinschaftsaufgabe Verbesserung der regionalen Wirtschaftsstruktur [GRW]) (BMWi, 2020, p. 17[25]). The programme provides about EUR 75 million per year for R&D projects and R&D-related investments. The R&D projects are usually performed by the institutes without external partners. Knowledge transfer towards industry takes place through contract R&D for SMEs and other firms, based on the knowledge and technologies obtained from publicly funded projects.

WIPANO – Knowledge and Technology Transfer through Patents and Standards

A programme that is key to the commercialisation of public research results through channels other than start-up creation, WIPANO has supported universities and non-university research institutions in identifying, protecting and exploiting economically promising research results since 2016 (BMWi, 2020[25]). Companies (primarily SMEs), universities, universities of applied sciences and non-university, publicly funded research institutions are eligible to apply to one of four funding lines. WIPANO extents about EUR 26 million in funding per year.

5.3.4. Closeness to the market

The fourth programme family, "Closeness to the market", comprises two major innovation policy programmes. Launched in 2019, the Innovation Programme for Business Models and Pioneer Solutions (Innovationsprogramm für Geschäftsmodelle und Pionierlösungen [IGP]) is a new pilot measure that funds non-technical innovations by self-employed persons, start-ups and SMEs, often in digital and service industries. IGP funds different vehicles, including experimental projects and feasibility tests; market tests and pilots; and cross-sectoral innovation networks consisting of at least five SMEs which are supported by a network management institution, and whose actors exchange knowledge on cross-sectoral innovation topics, develop ideas and implement innovations.

Zentrales Innovationsprogramm für den Mittelstand (ZIM)

The major instrument of open support for SMEs' R&D activities is ZIM, which emphasises co-operation and networking activities targeting SMEs' innovation performance in all technologies and sectors (BMWi, 2020[25]). ZIM has been administered by BMWK since 2008, when it was launched as a merger of several predecessor programmes. Since its introduction in July 2008 and up until June 2018 included, ZIM had funded over 28 000 projects by nearly 18 000 companies, of which 47% were first-time applications (Kaufmann et al., 2019[36]). In 2019, ZIM supported more than 3 550 projects with EUR 559 million. With its three programme pillars (individual R&D projects, R&D co-operation projects and networks), ZIM is in terms of volume one of the most important instruments of innovation policy in Germany.

A recent evaluation shows that ZIM has a well-defined position in the national funding portfolio thanks to its bottom-up attributes (no thematic delimitation), focus on experimental development in SMEs, project sizes and funded cost types, as well as the reduced administrative effort for applicants (Kaufmann et al., 2019[36]). The number of applicants who are funded for the first time by ZIM is high, which is a positive indicator of the programme's openness. In the Kaufmann et. al assessment of the ZIM programme, the authors found that participation in the programme had a positive effect on R&D turnover intensity. For a representative company, the effect is estimated at 4 to 6 percentage points – which, based on an average 4.3% R&D turnover intensity, corresponds to around doubling. ZIM has already significantly reduced the administrative requirements and is therefore also suitable for SMEs with little R&D experience.

Compared to BMBF or EU programmes, ZIM mainly targets companies with a less-pronounced R&D inclination. However, the demands on the level of innovation of the applicant projects, and the level of

contributions by the companies, favour companies with more R&D experience. One empirical analysis showed that the effect primarily exists at the level of additional R&D in companies that are already active in R&D (Kaufmann et al., 2019[36]). This means that regularly R&D-active companies can maintain their level more easily thanks to the funding, and that previously irregular R&D-performing companies can conduct more follow-up projects. To a much lesser extent, ZIM also appeals to companies that originally performed little or no R&D. ZIM funding guidelines were adjusted in 2020, and now offer better conditions for co-operative innovations and first-time innovators. One of the reasons for these adaptations was the need to ensure higher complementarity of ZIM with the new R&D tax credit.

5.3.5. Related programmes

This section summarises other programmes with objectives related to the "From the idea to market success" initiative.

Support for cluster initiatives

At the federal level, Germany has a respectable history of cluster initiatives dating back to the 1990s. BMBF has traditionally funded ambitious, science-based clusters, such as in biotechnology. More recently, it funded the "Leading-Edge Cluster Competition" (2007-17), which supported 15 Clusters of Excellence and their partners, and is currently running the "Clusters4Future" competition. Since 2012, BMWK has funded the "go-cluster" programme, covering technical services and advice rather than R&D. Multiple regional cluster schemes complement these initiatives. For example, as part of the "Innovation and Structural Change" initiative and previous programmes, BMBF has run a series of regional innovation initiatives in the "New *Länder*" and structurally weak regions in the western part of Germany, with the aim of reducing regional disparities. The Federal Ministry of Education and Research (BMBF), for its part, has supported over 500 regional initiatives since the 1990s to strengthen regional innovation systems.

Support for science and technology-based start-ups

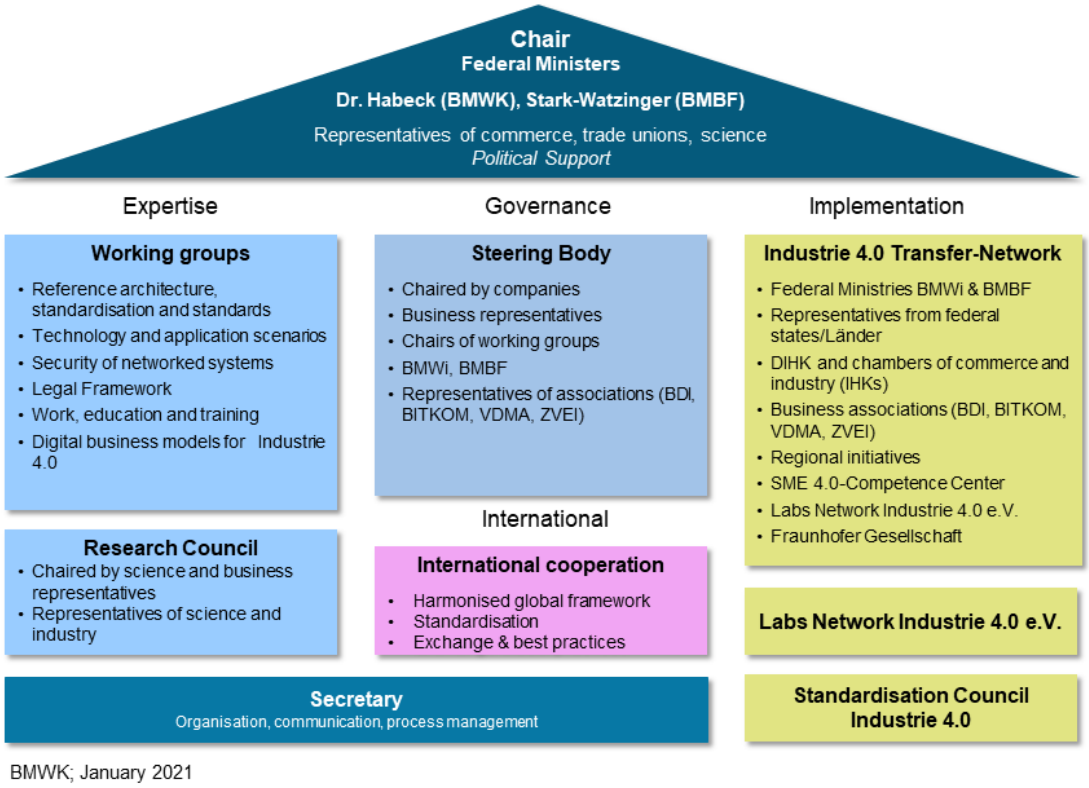
BMWK, BMBF and Länder governments provide a wide palette of support for science and technology start-ups. As an early step in the innovation chain, the "Validation of the technological and societal innovation potential of scientific research (VIP+)" and "Research at Universities of Applied Science" programmes administered by BMBF support universities in taking scientific ideas further, by funding both R&D and validation (proof-of-concept) projects. The BMBF initiative "StartUpSecure" supports young companies (particularly start-ups) in developing new ideas for IT security. The BMBF initiative "Enabling Startup – Unternehmensgründungen in den Quantentechnologien und der Photonik" aims to transfer innovative ideas in quantum technologies and photonics from universities and research institutions to spin-offs for application and commercialisation. To this end, it will particularly fund alliances between individual start-ups and university or research institutions.

Industry 4.0.

Industry 4.0 is a platform engaging about 150 organisations. Its purpose is to encourage, co-ordinate and disseminate information about the opportunities offered by more advanced and systemic digitalisation in manufacturing. Within the two funding programmes "Autonomik für Industrie 4.0" and "Smart Service Welt", the BMWK is providing nearly EUR 100 million for R&D for innovation. (BMWK, 2022[37]). The project was proposed in 2013 by an Acatech working group with wide membership across the manufacturing industry and research (Acatech, 2013[38]). The BMWK and BMBF ministers lead the platform, together with a committee of senior industry and research figures. Key activities include running working groups (listed in Figure 5.8) to define and co-ordinate responses to issues, as well as providing broad information and advice services in the Industry 4.0 Transfer Network (which includes regional centres) as well as the Mittelstand-Digital network, particularly to serve the *Mittelstand*. While the platform funds work to showcase

examples of successful projects, it relies on the ministries' ordinary R&I support programmes to fund R&I projects.

Figure 5.8. Organisation of the Industry 4.0 platform (2022)



Source: BMWK (2022[39]). Structure of the Plattform Industrie 4.0, Federal Ministry for Economic Affairs and Climate Action (BMWK), https://www.plattform-i40.de/IP/Redaktion/EN/Bilder/graphic-plattform-4-0.html (accessed 1 August 2022).

Zukunftsfonds (Future Fund)

Jointly managed by BMWK and KfW, the Future Fund aims to expand (both qualitatively and quantitatively) the federal support architecture, particularly the financing options available to start-ups in the capital-intensive scale-up phase (BMWK, 2022[40]). The government has allocated EUR 10 billion have for the fund's investments and costs. The ERP Special Fund also makes financial contributions to several components of the Future Fund.

The concept of the Future Fund, which covers a ten-year funding period, is to increase the available capital stock through successful investments and thus create a greater volume for re-investment without negatively impacting the budget. Several components of the concept are already available, and additional elements are currently being developed and implemented. The various components are closely linked and serve as a toolbox. The instruments will be adjusted, especially as regards the volume of allocation, taking into account the changing market environment and new needs. Further public and private investors are to make funds available for the various components, bearing the related risks of these funds. The following components have already been launched:

- **ERP/Future Fund Growth Facility:** KfW Capital is investing up to EUR 50 million per fund through this facility. Together with its ERP Venture Capital Fund Investment programme, KfW Capital can consequently now invest up to EUR 75 million per fund. KfW Capital will thus contribute to increasing the fund volumes of VC funds in Germany and Europe, facilitating more frequent and larger financing rounds for start-ups. A total of EUR 2.5 billion will be available up to 2030 for the ERP/Future Fund Growth Facility.
- **GFF-European Investment Fund (EIF) Growth Facility:** in line with the existing ERP-EIF Growth Facility, a new growth facility with a volume of up to EUR 3.5 billion was established to invest in growth funds and growth-financing rounds for start-ups. Again, larger fund volumes can facilitate more frequent and larger start-up financing rounds.
- **DeepTech Future Fund:** a new investment fund in the field of deep tech, the DeepTech Future Fund will be financed on a long-term basis by the Future Fund and the ERP Special Fund. Its purpose is to help deep-tech companies with validated business models grow sustainably while remaining independent. To this end, the DeepTech Future Fund always invests together with private investors. The aim is to support deep-tech companies as an anchor investor on their way towards capital-market maturity. The fund will further strengthen Germany as an innovation hub, as it provides a long-term perspective and makes the country more attractive to high-tech companies. Up to EUR 1 billion is expected to be available for the DeepTech Future Fund over the next ten years.

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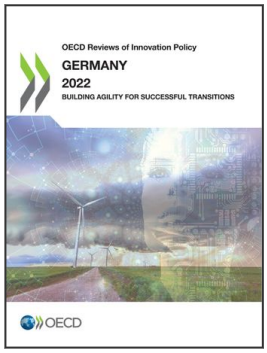

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