UNIVERSITY OF CAMBRIDGE

BABBAGE FORUM

Country Study: Germany

Christian Rammer

March 2023

Cambridge Industrial Innovation Policy

Contents

Mannheim, Germany | March 2023

Introduction

Industrial Innovation Policy (IIP) in Germany does not represent a uniform policy approach that is designed and delivered as such, but rather comprises various policy activities from different areas governed by different actors. In the German policy-making system, the following policy areas constitute the central parts of IIP:

- **Research and technology policy**: This policy area is mainly linked to the funding of R&D activities both in the science and the enterprise sectors. Specific features of German research and technology policy include a focus on **technology programmes** (i.e., R&D is provided for R&D in certain fields of technology and pre-defined areas of technical advance, see the Processes chapter for more details) and a focus on **collaborative R&D** involving both enterprises and science organisations (universities and public research organisations).

- **Innovation policy**: This policy area comprises activities to support the introduction and commercialisation of new products and processes along the **entire innovation chain**, i.e., from starting innovative businesses and conducting R&D in firms to the adoption and diffusion of new technologies and the growth of young innovative enterprises. Innovation policy is strongly linked to the SME sector (though based on a German definition of SMEs which includes so-called mid-range companies with several thousand employees). It also includes actions for innovation-conducive conditions, including an effective IPR system, standardisation, and technical infrastructure for innovation (e.g. sector-specific R&D infrastructure for SMEs, metrology, and technology consultants).

- **Industrial policy**: This policy area mainly follows a sectoral approach and aims at promoting **competition and competitiveness** of individual industries. While competition is promoted through traditional instruments of competition policy (antitrust law, reducing entry barriers), promoting competitiveness requires an industry-specific approach that reflects the different situations in each industry. In general, a high skill level and a sufficient supply of skilled labour, incentives for R&D and innovation (including the adoption of new technology such as AI), advanced technical infrastructure (particularly related to digitalisation) and low input prices (particularly through global sourcing) are key policy targets.

To understand IIP in Germany, it is useful to bear in mind some distinct features of the German economy:

- **Strong focus on manufacturing**: Different to most other advanced economies, Germany has maintained a large manufacturing sector. The share of manufacturing output in GDP has been more or less stable over the past 20 years (at around 25%), although a great transformation of manufacturing towards servitisation and digitalisation has been taking place. Nevertheless, there is still a significant traditional manufacturing activity, including some energy and transport-intensive activities (chemicals, steel, non-ferrous metals). The importance of manufacturing goes beyond its mere share in GDP and includes strong value chain links to many service sectors, including engineering, software, and logistics.

- **Very high export orientation**: Among the large economies in the world, Germany is the economy with the highest export and import shares and the highest trade surplus per GDP. Over the past two decades, about 5-7 per cent of Germany's GDP resulted from net exporting, i.e., exports that exceeded imports (including both goods and services). The trade surplus largely rests on the manufacturing sector. In the service sector (including tourism), imports exceed exports. The dependence of Germany's wealth on supplying other countries with manufactured products has several implications for IIP. First, the main competitive advantage of German industry is innovation (not price), hence maintaining a technological advance and being the first to exploit new technology is most critical. Secondly, a stable and strong national currency is vital to reduce uncertainty in international business and to profit from low import costs for energy, raw materials and standardised intermediary products. German industry is usually not focussing on the revaluation of currency for maintaining competitiveness since the demand for many products is not very price elastic (e.g. in the automotive or machinery industries). Thirdly, Germany is most dependent upon open markets and a well-functioning global transport system, including access to emerging economies (most importantly China).

- **The special role of professional education**: The German education system is characterised by a high share of students leaving education with a secondary degree while the share of university graduates is low (though rising). The usual way of secondary education is to complete a vocational training programme. These typically three-year programmes combine school-based education and on-the-job training in enterprises. Students are employed by the enterprise based on a special employment contract for apprentices. There are currently 324 vocational training programmes. There are three special features of this type of education: it transmits specialised knowledge and (technical) skills required for the specific occupation, it gives high priority to high-quality execution of tasks (in the tradition of craftsmanship), it provides incentives for graduates to stay in the specific occupation, acquiring additional specialised knowledge through learning-by-doing.

In terms of **terminology**, it is important to note that R&D and innovation are often used synonymously both by German industry and policy. 'Promoting innovation' by the government often means supporting R&D activities in firms or science organisations. Innovation activities not related to R&D rarely receive direct government support, albeit innovations not based on R&D are highly relevant in the German innovation system (see Som 2012, Rammer et al. 2009).

While the term 'industrial innovation policy is not common in German policy, actual innovation policy has a strong focus on manufacturing industries. Service sectors, except for software and R&D services, are much less addressed by innovation policy measures.

Another important term in German IIP is *'Mittelstand'* since many innovation policy activities, at least in policy rhetoric, is targeted at firms from the *'Mittelstand'*. The term is often translated into English by the 'SME sector', though this translation may be misleading. *'Mittelstand'* goes beyond the mere size of enterprises and refers to a certain style of management and strategy (e.g. family-based, long-term growth orientation, cooperative management that actively involves employee representatives). Several IIP measures only target SMEs, while others aim at prioritising SMEs. The definition of 'SME' varies by programme, however, and does not always follow the EU definition, but often includes 'mid-sized' companies of up to annual sales of 500 million Euro.

German IIP is naturally closely related to the specific strengths, weaknesses, opportunities and threats of the German innovation system. The following table is taken from an unpublished background report (see Rammer et al. 2022) for the OECD's review of innovation policy in Germany which will be published in October 2022.

Strengths, weakness, opportunities and threats of the German innovation system[1]

Strengths	***Opportunities***
• *A highly innovative and export-oriented manufacturing sector* • *A large number of innovation-oriented firms that are world-leaders in their respective markets, including many small and mid-sized companies ('hidden champions')* • *A strong science base with world-leading research in various disciplines, including natural science, engineering and medicine* • *High level of science-industry interaction, based on a multitude of interaction channels* • *Division of labour in a well-defined public research landscape (mission orientation), high autonomy at the level of R&D performers* • *High international orientation, both in terms of markets and knowledge exchange* • *Well-educated workforce (strong vocational training system)* • *A strong policy commitment to provide framework conditions conducive to innovation, including a steady increase of government financing of R&D* • *Holistic policy-making (innovation system perspective)*	• *A strong market position of many firms in emerging economies, foremost China, enables German industry to participate in increasing demand for innovative products and services* • *The regional balance in R&D and innovation capacities within Germany limits the dependence on only a few innovation hubs and encourages innovation competition among regions* • *The diversified industry structure with many innovation-oriented firms also in low-tech industries creates a large variety of innovation opportunities and can limit the dependence on a few industries such as automotive* • *The focus of engineering and natural sciences on research related to the industrial application provides a constant flow of new research results that can be taken up by an industry or can be the base for high-tech start-ups* • *The high international reputation of industry (Made in Germany) and of the German science system*
Weaknesses	***Threats***
• *Shortage in supply of skilled labour, resulting from demographic change as well as a large share of pupils leaving secondary education with low skill level* • *Weaknesses of the educational system in terms of curricula, institutional settings, pedagogic concepts, early selection into education paths* • *A decreasing number of start-ups, including high-tech start-ups, is mainly a result of the high demand of industry for skilled workers which raises the opportunity cost of entrepreneurship* • *Rather low levels of venture capital investment* • *Restrained uptake and diffusion of new forms of digitalisation in certain areas of the economy and society* • *The federal system complicates policymaking and does not support rapid changes* • *Low level of innovation in many service industries* • *Strong focus on incremental innovations with few radical/disruptive innovation activities*	• *Interruption in global exchange (barriers to international trade and communication) can hit the industrial business model of Germany as value chains and sales are highly globalised* • *Dependence of the industrial innovation system on the automotive industry and its demand for innovative solutions in many supplier industries can distract suppliers from reaching out to alternative markets* • *Slow uptake of new technological paradigms* • *Combating climate change forces a re-organisation of the entire mobility system, urging the automotive sector to change technology (e-mobility or hydrogen power), its product portfolio and its production facilities substantially* • *The energy transition towards renewable energy sources will require a substantial reorganisation of energy-intensive activities, including several manufacturing industries (chemicals, metals)* • *Focus on medium-tech industries (automobile, machinery, chemicals, electrical engineering) which can get under increasing pressure from emerging economies*

[2]

[1] ZEW and Fraunhofer ISI
[2] Rammer et al (2022)

Organisations

Owing to the federal architecture of the German political and government system, IIP is designed and delivered both by the Federal Government and the 16 State Governments. The division of labour between the two levels is only partially described by constitutional law and largely rests on informal coordination and a division of labour that emerged over time by different intensities of action in different policy areas by different government levels. In practice, both the Federal Government and the State Governments are free in designing and delivering their policy approaches, which often results in parallel and poorly coordinated activities and a large variety of funding schemes and policy programmes. As a rule of thumb, Federal schemes and programmes in IIP are more significant in size and scope than those operated by State governments, though there are some exceptions (e.g. the State of Saxony runs a large R&D support programme for firms co-funded by EU structural funds, and the Bavaria Government runs a large AI programme).

One area of a constitutionally defined division of labour with relevance to IIP is education, which is the main responsibility of the State governments. This includes the university sector, which is regulated by State law and receives institutional funding from State Governments. For the vocational training system (the so-called 'dual system' of professional training programmes that take place at vocational schools and through on-the-job training in enterprises), State Governments are responsible for the school part, while the Federal Government is responsible for the enterprise part and the legislation of the dual system.

The main actors associated with designing and delivering industrial innovation policy (IIP) in Germany at the **Federal level** include:

- The **Federal Ministry for Economics and Climate Action** (BMWK) is the Federal Government's unit that designs 'innovation policy', which stretches from support to innovative start-ups, co-financing of R&D in firms and collaborative R&D with science, and the support of the VC industry to set framework conditions conducive to innovation (IPRs, standardisation, technical-scientific infrastructure). The BMWK is also responsible for digitalisation policies, although the newly formed government moved part of these activities (related to digital society) to the BMDV (producing several overlaps between BMWK and BMDV). The BMWK designs and delivers most sector-specific industrial policies, including manufacturing and energy supply, but excluding digital services and transport industries (which are governed by the BMDV). The BMWK is also responsible for the Federal Government's general economic policy, including competition and macroeconomic policy (the latter in close cooperation with BMF), trade policy, and SME-related policies.

- The **Federal Ministry for Education and Research** (BMBF) provides funding for R&D-performing organisations outside the university sector (e.g. Fraunhofer, Helmholtz, Max Planck, Leibniz) and the German Science Foundation (DFG). The BMBF is also responsible for the majority of Federal **technology programmes**. These programmes provide project-based funding (and rarely also funding for R&D infrastructures) for firms and science organisations in various fields of technology (e.g. ICT, nanotech, biotech, new materials, photonics, production technologies, environmental technologies, transport technologies, food technology, building technologies, etc.). Some technology programmes, e.g. on energy and space, are operated by BMWK, however. Another BMBF responsibility is the design of vocational training programmes.

- The **Federal Ministry for Digital and Transport** (BMDV) has received more competencies in the field of IIP with the formation of the new Federal Government in November 2021. The BMDV is not responsible for digital society issues, which strongly overlap with other responsibilities in the field of digitalisation that remained with the BMWK (e.g. each ministry has a department for promoting AI). It remains to be seen how effectively and efficiently this new division of responsibilities works.
- The **Federal Ministry of Finance** (BMF) mainly affects IIP through its tax policy, including corporate taxation, energy taxes and tax exemptions for R&D (introduced in 2020), as well as other macroeconomic policies.

At the level of States (*'Länder'*), IIP predominantly takes place through dedicated, often small-scale, innovation programmes that target various thematic areas. These programmes are typically operated by the Ministries for Economic Affairs or the Ministries for Science. Ministries for Science are important players in IIP at the level of State Governments since institutional funding of universities, and the regulatory framework under which universities operate is provided and determined by State Governments. A study conducted in 2016 showed that there were 199 different IIP measures operated by the 16 State Governments (Rammer and Schmitz 2017: 66f).

There are only a few **independent agencies** in German IIP, although a large number of public and private organisations support IIP both in terms of reviewing needs for policy intervention and designing programmes, and in the administration and evaluation of programmes:

- The last Federal Government (Merkel 4) founded a new agency called 'Federal Agency for Disruptive Innovation' (**SPRIN-D**). The goal of SPRIN-D is to create new disruptive innovations (products, services and systems that make lives noticeably and sustainably better). SPRING-D provides finance, helps to put together teams (projects) and links these projects with the networks from science, business and politics.

- The newly founded Federal Government announced the creation of a new agency called the 'German Agency for Transfer and Innovation' (**DATI**). At the time of writing this report (August 2022), DATI did not start to operate, however. It is said that a focus of DATI will be on regional technology transfer, particularly by involving the group of 'University of Applied Sciences' (these are teaching-oriented universities focussing on engineering and management).

- The state-owned bank **KfW** is the main actor in delivering policy programmes in various policy areas. In the field of IIP, the KfW runs a digitalisation and innovation loan programme as well as several loan programmes linked to the diffusion of environmental technologies.

- **Programme administering agencies** ('Projektträger') comprise a large group of organisations (some are public bodies, others private companies or non-profit organisations) that provide a large range of services to the government related to funding programmes. These services are commissioned based on competitive tenders on a multi-annual base. The services typically include a review of needs for policy intervention, monitoring technological developments linked to a certain programme, designing the programme and the instruments (measures), managing application processes (including the preparation of funding decisions), paying out public money to beneficiaries, controlling project success and output, and monitoring and evaluating programmes.

At the level of State Governments, an important group of IIP actors are the state-owned banks of each State (*'Landesbanken'*). They often deliver IIP measures of State Governments, including grant-based schemes.

Another group of actors that takes on an important role in delivering IIP are '**technology organisations**'. These organisations are characterised by conducting R&D and providing education and training in fields highly relevant to industry and actively engaging in the transfer of new technology to the business sector. They are also important partners for the industry in cooperative R&D programmes such as the technology programmes or the Central Innovation Programme (see section 4 on Content for more details). There are four types of such technology organisations in Germany:

- **Fraunhofer**: Fraunhofer is a non-profit organisation devoted to the development and diffusion of new technology relevant to a wide array of industries. The organisation was founded in 1949 as part of an initiative of industry, science organisations, the state of Bavaria and the federal government as an independent association. Today, Fraunhofer runs more than 75 research units (institutes), each specialised in a specific field of technology, and employs about 19,900 FTE (2020). About a third of the annual budget of currently about €2.9b is provided through institutional funding (90% by the federal government, 10% by the state governments). Another third of the budget comes from contract research for industry while the remaining third is other third-party funding for R&D (e.g. federal technology programmes, ZIM, EU programmes). The Fraunhofer Society is steadily growing (in 2000, the number of employees was 7,300 FTE) both by founding new institutes and by integrating institutes of other organisations provided the institutes fit into the Fraunhofer model. Key features of the 'Fraunhofer model' are direct interaction with industry (e.g., through joint R&D projects, personnel exchange, and industry representatives in the institutes' boards), a focus on contract research, and high autonomy of institutes.

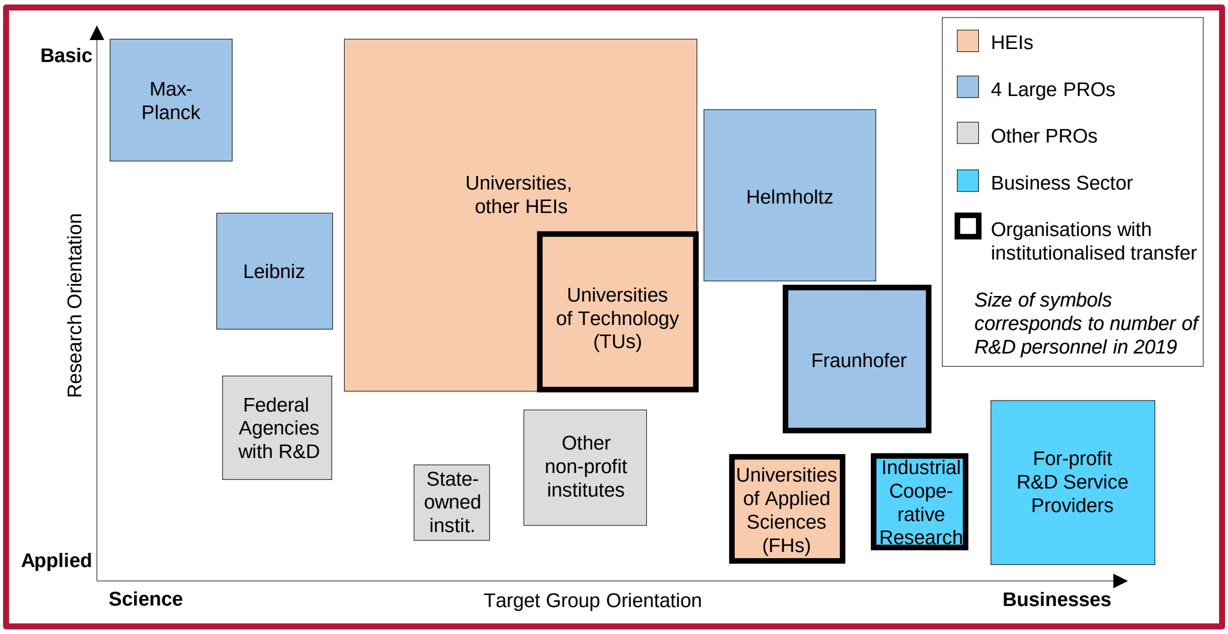
- **Co-operative industrial research institutes**: This group of independent, non-profit organisations comprises more than 100 institutes (with about 5,000 FTE R&D personnel) that conduct science-based applied R&D similar to Fraunhofer. The main difference to Fraunhofer is that each institute is legally independent and does not receive institutional funding from the government, but project-based funding through two dedicated public R&D programmes. Co-operative industrial research institutes are represented by two organisations, the *Arbeitsgemeinschaft industrieller Forschungsvereinigungen* (AiF, organisation of industrial research associations) and the Zuse Association. One funding programme for these institutes is called 'Industrial Co-operative Research' (German abbreviation: IGF) and provides about €200 million in funding per year for R&D relevant to SMEs from the industry. Funding through this programme is distributed by AiF to both its member institutes and universities and other research organisations. The other funding programme is called INNO-KOM and provides about €75m per year for R&D projects and R&D-related investments of cooperative industrial research institutes provided they are located in regions with structural problems (which cover about half of Germany in the Government's definition).

- **Technical Universities**: Knowledge transfer between industry and universities has a longstanding tradition in Germany that dates back to the 18th century. At this time, the first specialised research and higher education institutions have been established to supply industry with scientists and engineers, and to perform R&D in science and engineering to solve industry problems (Braunschweig

1745, Berlin 1770). A larger number of such institutions were founded in the 19th century and were called '**technical universities**' (*technische Hochschulen*). In the second half of the 20th century, some more universities of technology (TUs) have been founded. Today, there are about 20 such universities, though not all use 'technical' or 'technology' in their name. In terms of governance and funding, they do not differ from other universities. However, they show some special characteristics that constitute their special role in the system of knowledge transfer. First, they operate large engineering faculties. These faculties traditionally focus on applied research. By training engineers who usually move to industry after graduation or start their own business, close person-based networks between researchers at engineering faculties and industry researchers have evolved. Secondly, for being appointed as a professor, industry experience is often required, which often means having worked in an R&D department of a company. Thirdly, financing of faculties is traditionally based on a large share of industry R&D contracts, including joint supervision of the thesis by the faculty and enterprises. Fourthly, professors at TUs often found independent organisations to carry out contract R&D with firms (so-called 'An-Institutes'). These organisations are usually closely integrated into the university (e.g., they are located on the campus) and mainly employ graduates of the university and PhD students. An-Institutes constitute a special and important form of institutionalised transfer between universities and industry (see Schmoch 2003). In 2006, 9 TUs established a union called TU9 German Universities of Technology to represent the common interests of this type of university.

- **Universities of Applied Science**: Another group of HEIs that shows several features of institutionalised transfer are the so-called **Universities of Applied Science** (*Fachhochschulen - FHs*). They have been established since the end of the 1960s, often by upgrading secondary-level schools focusing on engineering or other industry-related subjects (*Ingenieurschulen, Fachschulen*). After 1990, a large number of FHs were established in East Germany. Their main mission is to supply the business sector and other public or private organisations with skills that are specifically required in certain sectors and types of occupations (see Wissenschaftsrat 2002, 2010, 2016). For industry, FHs mostly specialise in engineering, IT and management skills. Graduates from FHs tend to work in different areas of a firm, R&D being one but not necessarily the dominating one. In addition, most FHs perform applied R&D, motivated by and oriented on practical problems of industry. A special federal programme (Research at FHs) provides dedicated funding for applied R&D, knowledge and technology transfer as well as research-based education of students. Transferring the results of this research into industrial practice is a key component of FH activities. Most FHs run separate institutes or companies for performing this transfer (e.g., institutes for applied research). From the 1970s on, **Steinbeis Stiftung** provided an organisational umbrella for technical consulting services offered by professors at FHs. Initially focussing on FHs in Baden-Wuerttemberg, there are Steinbeis institutes now in all states. By the end of 2019, the Steinbeis group comprised 1,073 firms operated by 637 professors and has 2,135 employees and 3,471 freelancers. The total turnover of these firms was €170m in 2019.

***Science-based R&D performing organisations in Germany by research orientation and target groups*[3]**



HEIs: Higher Education Institutions

[3] Source: ZEW

Processes

The process of developing, designing and delivering IIP in Germany does not follow a pre-defined model but is very much characterised by bottom-up approaches with rather high autonomy of individual actors. Key characteristics of IIP making in Germany include:

- Policies are typically implemented through **decentralised (often small-scale) policy actions** (programmes, schemes, measures, initiatives) that are developed and implemented by individual units of ministries. The legal status of these actions is either a dedicated budget line in the ministries budget (approved by parliament through the annual government budget law) that allows the ministry to fund activities that fall under this budget line or a directive which is issued by the ministry as part of its administrative power. This type of policymaking implies that parliament is usually not involved in any IIP activity, except if a specific IIP action requires changes to existing law (e.g., if tax incentives to propel the demand for certain new technologies will be implemented). For this reason, IIP making is very much driven by technical experts in ministries and intermediary organisations while members of parliament are rarely involved in the process.

- Both at the Federal and the States levels, **ministries** play a decisive role in IIP making. They not only fund policy actions but also actively identify challenges and needs for policy intervention (often through studies commissioned by academia or private consultants) and design policy responses in great detail in-house. In contrast to many other countries, agencies (such as Vinova in Sweden) do not play a major role in IIP-making in Germany. Within ministries, IIP-making is a highly decentralised activity. In practice, each unit within a ministry is quite free to design new measures within its field of policy responsibility.

- The bottom-up nature of policymaking combined with the federal nature of the German state calls for **coordination** among the various organisations involved in policymaking. Over time, a multitude of coordination mechanisms both within the Federal Government and between the Federal Government and the State Governments have developed. Most coordination takes place on an informal base (e.g., by inviting relevant policy actors and stakeholders to non-public debates on policy actions). There are also a few formal coordination mechanisms such as the Joint Science Conference of the BMBF and State ministries of science to coordinate funding of universities and other science organisations (DFG, Max Planck, Leibniz).

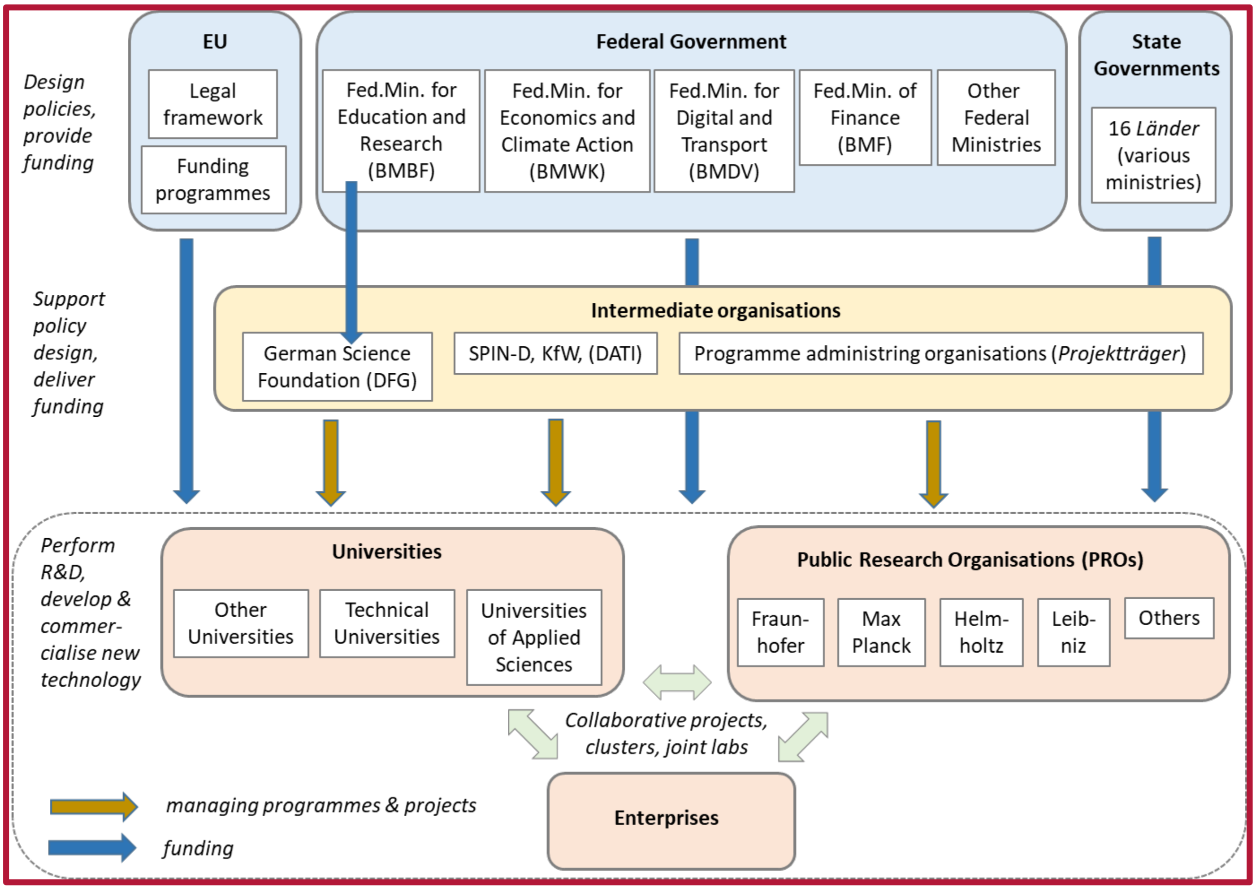
- **Industry representatives** are strongly involved in developing and designing (new) policy initiatives, and there is a substantial amount of intelligence on IIP at the level of industry organisations (e.g., in the automotive, machinery, chemical, electronics and software industries).

- A large network of **independent organisations** that review the innovation system and provide input to policy debates, including universities, public research organisations (PROs), and many private companies.

- There is a dedicated **advisory group on research and innovation** (Commission of Experts for Research and Innovation - EFI) which submits a report to the Federal Government once a year, summarising key policy issues and identifying needs for policy intervention. This report is closely monitored by the government and stakeholders and influences policy-making by putting forward specific topics.

The bottom-up approach to IIP in Germany has advantages and disadvantages. One advantage is that government can quickly respond to new challenges and can address very specific needs of small groups of actors in the innovation system by dedicated measures. A disadvantage is that the set of policy actions in IIP has become very extensive, and even for experienced experts in a field, it is difficult to oversee all policies at the different government levels. Coordination among different policy actions is also often poor, resulting in overlapping programmes. Another disadvantage is that in case new policy measures require the involvement of actors from different government organisations, processes of policy design can become very complex and slow. For example, a new R&D tax credit was introduced only in 2020, after 15 years of policy debate and several attempts to put forward a new law for this measure.

Map of organisations in IIP policy implementation in Germany



The High-tech Strategy (HTS), introduced in 2006 for the first time and renewed every four years since then, serves as a kind of coordination mechanism among Federal ministries (see section 5.), particularly for the general goals and contents of IIP. The new government has announced to continue the HTS with a new strategy called "Future Strategy Research and Innovation".

Evaluating Federal IIP programmes is now mandatory to pass a formal spending examination by the Federal Court of Auditors (*Bundesrechnungshof*). The 'evaluation culture' in IIP is much less developed, however, as compared to the UK or Scandinavian countries, concerning both the methodological standards and the feedback from evaluations into policy making. Evaluations are usually commissioned by the ministry units that are responsible for the measure to be evaluated and have a strong interest in a positive outcome.

Content

The content of German IIP is largely determined by two types of policy activities. First, financial contributions by the government to industry and the innovation system are mainly delivered through dedicated **programmes**. These programmes define eligibility criteria and target groups as well as the type and volume of public support. Secondly, **policy strategies and initiatives** for specific industries and technologies formulate the government's priorities and goals. These strategies and initiatives often combine a multitude of policy measures, including programmes, legislation and government-initiated infrastructure.

The general goals of IIP of the Federal Government are laid down in its **High-tech Strategy** (see section 5). The overarching goal of the strategy is to maintain and advance a leading role of German industry in technology, innovation and competitiveness in a wide range of industries and markets, and to respond to upcoming social, environmental and economic challenges.

The Federal Government operates a large number of **programmes** related to IIP. The most important ones include:

- **Central Innovation Programme** (ZIM): This programme provides financial support for R&D projects in SMEs (up to 500 employees) through grants. Projects are usually collaborative projects involving universities or PROs. Grants typically cover 35% of the total project costs of firms and 100% of the project costs of science partners. The content of the projects is defined by firms and their collaboration partners. The annual budget of ZIM is currently about €600 million. Every year, several thousand projects receive funding. In 20

- **Technology Programmes**: There are about 20 different Federal technology programmes, mainly operated by the BMBF, but some also by BMWK and other Federal ministries. These are multi-year programmes, sometimes of significant size (e.g., 'ICT 2020 programme' ran for 12 years with a budget of €3.4 billion). The programmes define priority technology areas for which consortia from industry and science can apply for grant funding. Grants are typically much larger than ZIM and are also provided for large firms. Technology programmes may include other types of funding, e.g. for science infrastructures (e.g. the ICT 2020 programme funded a network of supercomputing infrastructure). Within the BMBF technology programmes, there is a special scheme for SMEs (called SME Innovative) which should simplify the access of SMEs to funding (as consortia tend to be large, and project proposals are quite demanding in terms of the detail of planned R&D activities, SMEs were reluctant to participate in the past).

- **Research Allowance**: This tax-based scheme was introduced in 2020 and offers a tax credit of 25% of eligible R&D costs (R&D personnel cost, 60% of cost of contracted-out R&D) with a ceiling of €4 million per year of eligible R&D costs (hence mainly supporting SMEs).

- **Technology Transfer Initiatives**: Technology transfer is the main priority of Federal IIP. The government has been experimenting with different types of measures to accelerate and broaden the transfer of knowledge and new technology between industry and science. Among the successful initiatives, one should mention the Leading-Edge Clusters ('*Spitzencluster*') which link firms, universities and PROs within a region for developing new technologies (15 clusters received funding of €600 million in total). The programme Research Campus encourages long-term cooperation between industry and science to accelerate the commercialisation of science-based new technologies. The programme funds both infrastructure (labs at universities) and the cost of R&D projects with up to €2 million per year and campus for up to 15 years. There are nine such campuses today.

- **Support for innovative start-ups**: Three main Federal programmes are targeting innovative start-ups. The programme EXIST supports start-ups from universities, both through the financial support of start-up projects and by encouraging a start-up-friendly environment at universities (incl. education, incubators, and access to financing). The High-tech Start-up Fund is a public-private initiative that provides early-stage funding for high-tech ventures. The programme INVEST aims at increasing business angel (BA) investment in innovative start-ups by offering grants to first-time investments by BAs. In July 2022, the Federal Government published its new Start-up Strategy which puts a particular focus on funding fast-growing, innovative start-ups through mobilising more VC for growth both through additional government programmes and PPP initiatives. For this purpose, existing VC funds will be provided with additional money, and new funds will be established (e.g., the DeepTech Future Fund).

- **KfW programmes**: The KfW is a state-owned bank that provides a wide range of loan-based financing schemes. Most closely related to IIP is the Digitalisation and Innovation Loan which targets investment in digital technologies and innovative products by SMEs and mid-range companies. Other KfW programmes relate to investment in environmental technologies, renewable energy and energy efficiency, financing of start-ups, and growth investment in SMEs and mid-range companies.

- **Digital technology diffusion programmes**: The Federal government runs several schemes to support the diffusion of digital technologies (incl. artificial intelligence) in SMEs. The programme 'go-digital' is a voucher programme for IT consulting services. The scheme 'Digital Now' offers grants for IT-related investment and IT training on digital technologies. The Federal government initiated the establishment of 28 Competence Centres on IT and industry 4.0 technologies. These centres help SMEs in adopting digital technologies through information, demonstration and training services. The Digital Hub Initiative runs 12 centres that link start-ups, established firms and research on various topics related to IT. Another initiative offers support to SMEs on IT security in SMEs.

- **Innovation programmes for SMEs**: There are Federal voucher programmes that provide a small financial contribution to SMEs seeking external consulting services related to innovation (programme 'go-inno'). Similar programmes are offered by State governments. The programme WIPANO offers financial support to SMEs for applying for a patent and participating in industrial standard-setting activities.

A specific feature of IIP in Germany relates to **industry & technology strategies and initiatives** by the Federal Government. These strategies and initiatives address upcoming, long-term challenges as well as new social and technology trends relevant to the industry and formulate an integrated policy response that usually stretches from research and technology development to diffusion and markets.

On each strategy/initiative, the Federal Government typically publishes a strategy document that describes the challenge and how the government aims to respond to the challenge. The strategy is then implemented through a broad range of policy instruments and initiatives that may include R&D funding programmes, new infrastructure (e.g., demonstration centres for transferring new technology to SMEs), awareness measures, taxation, subsidies to technology users and even new factories (e.g. in case of battery technology by founding a 'research factory'). A common feature of all these government strategies and initiatives is to provide a coherent policy approach that aims at putting German industry into a leadership position in terms of technological advance and industrial competitiveness.
In the following, several current technology strategies are briefly characterised.[4]

Digitalisation: Activities of the German government to increase the use and benefit of digital technologies are manifold. In its report 'Shaping Digitalization. Implementation strategy of the Federal Government' (*'Digitalisierung gestalten. Umsetzungsstrategie der Bundesregierung*') of December 2020, the German government presents more than 130 digital policy initiatives, including infrastructure and equipment (e.g., high-speed broadband networks), innovation and digital transformation, digital competence, society in the digital transformation, and digital modernisation of public administration. The main focus is put on SMEs since digital technologies can help them to adapt to the requirements of a more flexible production environment, to the increasing need for highly specialized products, to the demand for product-accompanying services and to manage faster innovation cycles in general. Compared to larger companies, SMEs often do not have the internal expertise, investment possibilities or strategic focus for digital transformation. What is needed is awareness, information, demonstration, and support. The German Federal Ministry for Economic Affairs and Energy (BMWi) has been supporting the digital transformation of SMEs through its Mittelstand 4.0 Competence Centres (*Mittelstand 4.0 Kompetenzzentren*) since 2017 with more than 36 million EUR per year. In 2022, there were 27 operating Centres. Some of them have a regional focus, and others focus on cross-cutting topics like e-standards, usability, and interoperability. Mittelstand 4.0 Competence Centres offer neutral, cost-free information, demonstration, qualification and accompaniment. They offer workshops, visits to demonstration plants, meetings with experts and practical support for SMEs developing their digital solutions. Separate consortiums consisting of universities, Fraunhofer institutes and other external partners like chambers of commerce found the Mittelstand 4.0 Competence Centres. Within these consortiums, each partner takes over a specific role due to their specific competence (e.g., 3D printing, flexible manufacturing, new business models). All partners act together to promote the overarching topic of digital transformation (see BMWi 2019, p.5; Prodi et al. 2022).

Artificial Intelligence: The Federal Government focuses on the diffusion and use of AI in an enterprise context, especially targeting SMEs. In the context of its AI Strategy 'AI Made in Germany' ((*KI-Strategie der Bundesregierung*), which was adopted in 2018, the Federal Government promotes the transfer of findings from AI research to the economy as well as the use of AI across the breadth of the SME sector. Thematic fields of priority are mobility, health, environment and agriculture (Federal Government of Germany 2020, p. 5). The strategy bundles all AI-supporting activities of three ministries (BMBF, BMWK, BMAS). The midterm report of 2020 lists 48 measures and activities of the three ministries ranging from establishing new AI research centres at six German universities to starting an AI innovation competition to introducing AI experimentation rooms for the study of work-related changes due to AI, to opening an AI observatory to research societal impacts of AI. In December 2020, the German AI Strategy was reviewed to take into account new developments in the field. With funds from the German economic

[4] Texts are taken from Rammer et al. (2022).

stimulus package in response to Covid 19, the AI budget was increased to 2 billion Euros until 2025. This is a doubling of the original budget for the German AI Strategy.

Climate change and energy transition: The transition of the German energy system towards renewable energy sources has been a government priority since the late 1990s. The significance of this policy priority has been reiterated with the cuts in energy supply and the rise in energy costs resulting from the war in Ukraine. Awards to support the energy transition are distributed among different ministries. Key responsibilities lie with the BMBF (research programmes on sustainability), BMWK (energy policy, design of energy markets, research programmes on energy technology), BMU (climate policy), BMF (energy taxation) and BMVI (transport sector). Energy transition forms an important topic within the High-tech Strategy, which also aims at coordinating innovation policies between the different ministries. Other important coordinating institutions within the Federal Government are the State Secretaries' Committee for Sustainable Development and the *'Kabinettsausschuss Klimaschutz'* (Climate Cabinet).

Transformation of the automotive industry: The automobile industry has been playing a key role in Germany's economy, both in terms of its economic significance and its role in the German innovation system. More than a third of the total R&D expenditure of the German business enterprise sector was performed in the automotive industry. More than half of Germany's trade surplus is generated by this sector, and more than 7% of Germany's GDP is linked to the demand for domestically produced automobiles and automotive products (Legler et al. 2009). The German automobile industry is currently facing several challenges, including electrification, autonomous driving, new mobility concepts, and shifts in global markets. Both industry and policy have been responding to these challenges. Policy responses at the side of the federal government are strongly focussing on electric mobility and include the following initiatives and programmes:

- National Platform for Electric Mobility (NPE): started in 2010, the platform operated until 2018 and was then re-named the National Platform Future of Mobility (NPM). Based on a federal government programme 'Electric Mobility' published in 2011, the platform brought together industry, policy and research to coordinate the activities of different actors.

- Battery-cell production in Germany and Europe: Federal government provides one billion euros in funding from the Energy and Climate Fund until 2022 to establish Germany as a global leader in battery cell production under the European Battery Alliance

- Research factory for batteries (BMBF 2018) is an umbrella programme to develop new generations of battery technology. It includes funding of R&D on battery materials (about €72m), battery cell production technologies (€42m) and a demonstration plant for producing batteries (located in Münster, €150m). In addition to this programme, the federal government has been funding R&D on electric mobility at a significant level through different federal ministries (BMWi, BMU, BMBF). From 2010 to 2017, €2.2b of funding was provided. These programmes continue.

- Developing a market for electric mobility: Purchase grant (environmental bonus of €4,000 for new all-electric vehicle and of €3,000 for plug-in hybrid vehicles) of up to €600m in total to support the purchase of at least 300,000 electric vehicles by 2019; support for the roll-out of charging stations (€300m); increasing the number of electric vehicles in car fleets of public authorities (€100m);

extension of electric vehicles from the vehicle tax exemption for ten years; tax incentives for buying electric cars (special depreciation, reduction of the taxation of electric company cars); Law on Electric Mobility (2015) offering privileges for electric cars; standardisation of charging and payment systems; Law on Building and Electric Mobility Infrastructure (2020) to improve charging stations in buildings.

- Charging infrastructure: Masterplan Charging Infrastructure of the federal government; Charging Station Ordinance (amended in 2017) to harmonise authentication and payment at charging stations; financial support for establishing charging stations (€300m, by May 2020, applications for about 22,000 charging have been submitted).

- Electric mobility showcases: LivingLab BWe mobile (Baden-Wuerttemberg), International Electric Mobility Showcase Berlin-Brandenburg, 'horsepower is going electric' (Lower Saxony), 'Electric mobility links together' (Bavaria/Saxony); funding for 90 collaborative projects (consisting of 334 individual projects) received funding of almost €300m.

- Flagship projects: driveline technology, energy systems and energy storage, charging infrastructure and grid integration, mobility concepts, recycling and resource efficiency; information and communication technology.

- Autonomous driving: 'Strategy for Automated and Connected Driving - Remain a lead provider, become a lead market, introduce regular operations" (BMVI 2015). A follow-up report on the strategy (BMVI 2017) identified major R&D challenges. They were taken up by the new Federal 'Action Plan Automated and Connected Driving' from June 2019 (BMBF/BMWI/BMVI 2019). This plan can be interpreted as a joint research framework of BMBF, BMWi and BMVI, which bundles priorities and guidelines for the future orientation of research funding for autonomous driving. In particular, it calls for federal funding of research in cases in which various actors have to work together, or in which risky and disruptive innovations are involved. The three ministries announced the coordination of their respective research projects among themselves in an early stage. Furthermore, they call for an exchange about research activities in various fora organised by different Federal Ministries (BMVI, BMWK, BMBF).

Bioeconomy: The bioeconomy is expected to provide solutions to major economic, societal and ecological challenges like resource depletion, food insecurity or climate change. Germany possesses a strong and diversified knowledge base for bio-based innovations, e.g. technologies that are expected to contribute highly to sustainability, the use of bio- waste and environmental biotechnological methods and processes (Wydra 2020). However, the main challenges are the scale-up from the lab to a commercial product and market adoption. Still technological and market uncertainties persist, among others, bio-based products are often still not cost-competitive to fossil-based products. The gap between research and commercialization as well as public concerns can be conceived as rather high in Germany and commercialization and demand-oriented policies are widely missing. Those weaknesses are aimed to be addressed in the National Bioeconomy Strategy, which has been launched in January 2020 (BMBF/BMEL 2020). It succeeds and builds on the earlier National Research Strategy BioEconomy 2030 and the National Policy Strategy on Bioeconomy to pool the various political strands together into a coherent framework. The objective of the current strategy is to combine economy and ecology to ensure more sustainable use of resources. It encompasses a wide set of strategic goals ranging from generating biogenic resources sustainably, enhancing and applying biological knowledge, and developing solutions for the UN Sustainable Development goals, but also to involving society in the bioeconomy and strengthening national and international collaboration.

Hydrogen economy: The political and economic interest in hydrogen arises, among other things, from the importance of hydrogen in a greenhouse gas-neutral energy system. The focus in this context is on green hydrogen which is based on renewable energy. There are also high industrial policy expectations linked to hydrogen technologies. Moving ahead and basing steel and cement production on hydrogen is of future importance for staying competitive in these sectors. Furthermore, transportation poses specific challenges to reducing carbon emissions. Battery electric vehicles are seen as a major strategy for passenger cars but are a more difficult option for heavy-duty trucks. In the latter segment, fuel cells using green hydrogen are seen as another option. In aviation and shipping, hydrogen is also a discussed option to reduce carbon emissions. However, aviation and shipping require an energy input with high energy density (Wietschel et al. 2020). This makes synthetic fuels based on green hydrogen (Power to X) an interesting option in these two transportation modes. Both the Federal Government and several State Governments developed hydrogen strategies. In the National Hydrogen Strategy (NWS) from June 2020, the federal government relies on green hydrogen, because only this is 'sustainable in the long term' (BMWi 2020). The NWS contains 38 measures. By 2030, 14 TWh of green hydrogen should be produced in Germany. The federal government envisages building electrolysers with a capacity of 5 GW by 2030. Another 5 GW are to be created by 2035 or 2040 at the latest. Given the hydrogen demand forecast in the NWS for the year 2030, the federal government wants to cover only 13 to 16% of the demand with hydrogen produced domestically by electrolysis. Thus, the federal government assumes that Germany will import the majority of its hydrogen requirements. According to the federal government, hydrogen should initially be used primarily in industry and, to a lesser extent, in selected transport sectors such as air and shipping. Within the governance system of the NWS, the State Secretaries' Committee on Hydrogen coordinates federal policies. A National Hydrogen Council consisting of 26 members from Federal and Laender level ministries, experts and industry is the second pillar to broaden the integration. Both are supported by a Secretariat (*Leitstelle Wasserstoffstrategie*).

In addition to the strategies and initiatives presented above, there are numerous more similar activities related to other fields of technology, including microelectronics, nanotechnology, quantum technologies & photonics, production technologies, the aerospace industry, maritime technologies, new materials, and environmental technologies.

Good Practices and Example

The following text is taken from the background report for the OECD's review of innovation policy in Germany which will be published in October 2022.

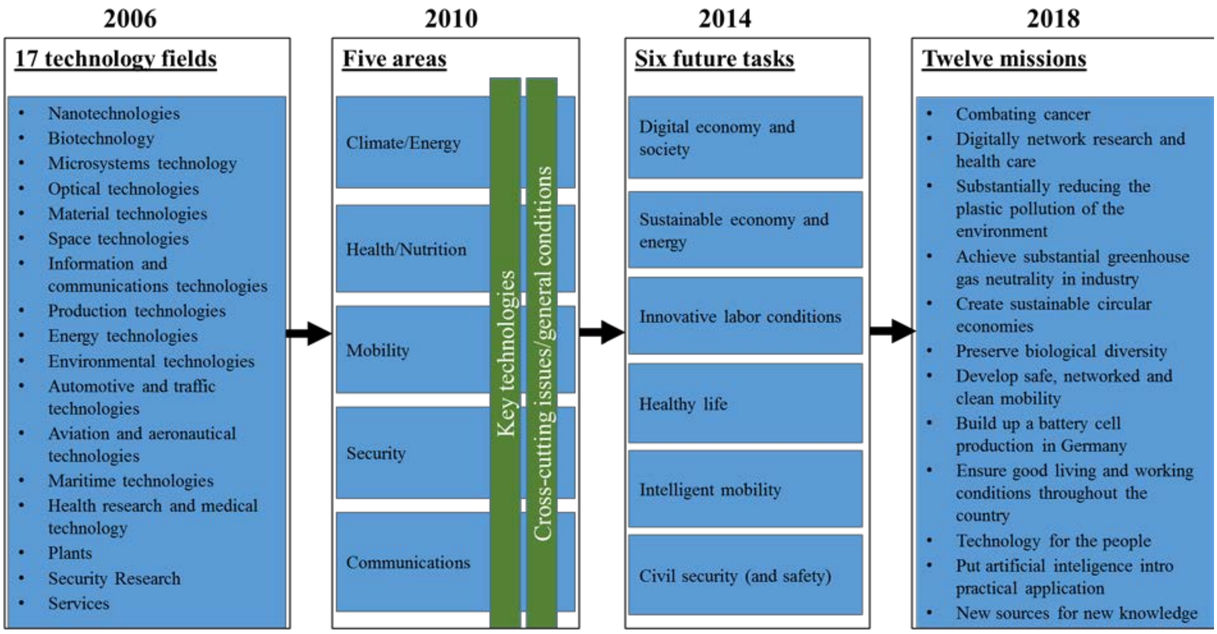
Germany's innovation policy landscape is characterised by differentiated, decentralized stakeholder involvement and can even be seen as fragmented in terms of responsibilities and attribution. In other words, bottom-up processes and multi-level, multi-actor contributions are the central characteristics of the German innovation system. In consequence, coordination of these policies, policymakers and other stakeholders is a prerequisite. While one approach to achieve coordination could be a central organisation of the tasks and coordination (e.g. a kind of 'Federal Innovation Agency'), the German government went a different way and rather focused on an 'orchestration' approach by developing overarching policy guidelines that provide a framework for decentralised policy-making at individual ministries and agencies. Since 2006 this guideline is called ***High-Tech Strategy****.*

The first High-tech Strategy (HTS) was introduced in 2006 as an umbrella for the existing innovation policies from all ministries of the German Federal Government that substantially fund science, technology and innovation. It had the aim to provide an 'a piece innovation policy' by coordinating and orchestrating existing programmes and policies. This aim persisted for the three following releases of the High-Tech Strategy that were published in each new legislative period (which lasts for four years). The first HTS was strongly technology-oriented and defined 17 technology fields of specific interest, covering the responsibilities and interests of many ministries. As the programmes and policy actions related to these technology fields were in many parts a continuation of existing policies, observers and analysts have criticized the HTS as being 'old wine in new bottles'. Another criticism related to the lack of reference or intersection with innovation policies by State governments or at the European level.

However, from today's perspective, clear changes to innovation policy and measurable effects have been achieved based on the HTS. In particular, next to the overall coordination effects across ministries and within ministries, several new policy approaches and perspectives have been introduced. For example, in the aftermath of the first HTS additional coordination and integration at the lower level of individual policy programmes occurred, e.g. as earlier SME tools by the Ministry for Economic Affairs and Energy (BMWi) like Pro-Inno, NEMO, or InnoWatt were integrated into the new ZIM programme (Zentrales Innovationsprogramm Mittelstand), which became the most important and effective SME programme in Germany and still is one of the largest innovation programs that currently reaches an annual budget of more than €500m. New policy approaches like the 'Leading-Edge Cluster' Competition as well as the Excellence Initiative were newly established during this first period of the HTS. The Pact for Research and Innovation was set up, which gives budgetary planning reliability to non-university research organisations. In exchange, they agreed to better coordinate, more intensively collaborate, and contribute to overarching policy objectives.

Overall policy goals like the 3% target (3% of GDP to be spent on R&D by 2010) as well as the 10% target (10% of GDP to be spent for science, technology and education) were explicitly formulated in the HTS. While the 10% target's public visibility slowly deteriorated and was not explicitly addressed in later periods, the 3% target continued and was just recently even increased to 3.5% (by 2025) after the 3% target was met in 2017. By the end of the first HTS, the number of researchers in the German innovation system increased by more than 100,000 persons - in public and private research labs - and the GDP share spent on R&D grew from 2.5% to 2.9%, with stronger increasing public budgets in this first period, due to the Financial Crisis and the delayed leverage effect of public spending. The first HTS definitely put science, technology and innovation higher on the agendas of policymakers and related stakeholders, leading to higher visibility and higher budgets for these matters.

Evolution of the German High-Tech Strategy: from technology to mission orientation



Source: Fraunhofer ISI, based on High-tech Strategy Documents by BMBF.

The second HTS (called High-tech Strategy 2020), released in 2010, introduced the idea of grand challenges - however, at that time still more as a word of mouth as the five areas (energy, health, mobility, security, communication) were mostly aggregates of the previously existing science and technology areas -, but still moving away from a strict technology focus towards a (basic) mission orientation. It also stressed societal impact and especially social participation as parts of policymaking. The third HTS (called the New High-Tech Strategy) continued the challenge orientation and introduced the so-called Future Projects, which were then the level of policy action and which come closer to missions as we would define them today. Most notably, the policy platforms gained importance and visibility during this period, among them the Industry 4.0 platform that was not only able to address the digitalization of industrial production, but also to establish a worldwide known trademark term. Further platforms of this kind followed and they became an integral part of German innovation policy-making (e.g. bioeconomy, future mobility and city of the future). The fourth edition of the HTS, called High-Tech Strategy 2025, was released in early 2018 and aimed to implement a mission-oriented innovation policy. It formulated twelve missions of very different granularity and applicability.

The High-Tech Strategy is accompanied by a consulting and monitoring body, the High-Tech Forum. Members are representatives from industry, science organisations and also civil society. The HTS is not evaluated as a whole, while individual programmes under the HTS are evaluated regularly. On the one hand, the High-Tech Forum partly takes responsibility as an accompanying consulting body. On the other hand, the HTS needs to be seen as an overarching policy guideline. The measurable and assessable policy aims and actions take place in the policies and programmes below the High-Tech Strategy. Based on this perspective, it could be said that the HTS is not a strategy in a strict sense as it just aims to coordinate the policymaking bodies of the federal government. It provides the guardrails also for other stakeholders at the federal level as well as for policymakers at the level of the federal states, in the scientific organisations and industry.

The following tables summarise the strengths, weaknesses, opportunities and threats of IIP governance and IIP mix in Germany. It is taken from the background report for the OECD's review of innovation policy in Germany which will be published in October 2022.

Strengths, weaknesses, opportunities and threats of IIP governance and IIP mix in Germany (Source: Fraunhofer ISI)

Strengths	Opportunities
• *Holistic science and policy making based on an innovation system perspective.* • *A strong policy commitment to provide a framework condition conducive to innovation, including a steady financial increase of government financing of R&D.* • *One goal of national innovation policy is to enable and accelerate structural transitions. It is addressed by targeted policies at the federal level and, in cases where the national level offers no dedicated policies, often complemented by the federal states.* • *Germany's innovation policy follows an inclusive approach that benefits from both regionally and thematically diversified organisation of the country's economy. Both federal and regional governments emphasise the aim to include and leverage the capacities of actors outside of main national centres and to complement locally incomplete clusters through regional and interregional networking.* • *Connected to the High-tech Strategy, institutional funding for PROs has been increasingly linked to overall policy objectives in the past 15 years while keeping the mission-specific distribution of tasks between the PROs.* • *Founding new ventures by scientists have been a key priority of federal and state government policies for 25 years.*	• *Shared responsibilities for innovation policies (in particular at the federal level) enable different government actors to address those challenges most relevant to their remit in a competent and targeted manner. The High-tech Strategy underlines and follows this approach, while, at the same time, strengthening interdepartmental and inter-agency coordination.* • *Moreover, national ministries put forward thematic strategies e.g. the Bioeconomy, Mobility and Energy. Even at a regional level, thematic emphasis is now more commonly defined and cast in concrete, targeted programmes, which are increasingly underwritten by substantive budgets and very concrete, high-level, concerted actions.* • *The newly established R&D tax incentive scheme will increase overall public support to firms, in particular to SMEs and is also expected to contribute to reaching the 3.5% goal (R&D spending as a share of GDP).* • *Innovation policy increasingly addresses innovation outside the (R&D-based) high-tech industry, also addressing non-R&D-performing innovative firms.* • *The 'Regulatory Sandboxes' approach is a recent means to lower barriers to innovation from regulation.* • *Agency for disruptive innovation (SPRIN-D) is a new approach to enable and trigger more disruptive innovation through DARPA-type research funding.*
Weaknesses	**Threats**
• *The federal system and shared responsibilities at the federal level between different ministries complicate coherent policy-making and do not support rapid changes.* • *Lack of skilled labour requires stronger links to reform education policies (abandon disciplinary 'silos' and strict curricula, instead foster inventive and entrepreneurial spirit) and to migration policies (because of the ageing society).* • *Still a strong research-oriented mode of innovation: Only a few (and small volume) programmes provide innovation-related funding apart from R&D, e.g. for business model innovation, and service innovation.* • *R&D support tends to favour the R&D of high-tech (manufacturing) industries as compared to R&D in the low-tech and service sector.*	• *Shared responsibilities and a resulting variety of innovation policy priorities lead to incremental changes in the overall policy approach and negative coordination. Transformative policy approaches to address climate change and other challenges might remain small-scale and incoherent.* • *This is exemplified by the broad approach taken by the High-tech Strategy, which is open for almost all thematic research areas in one way or the other, resulting in a low factual governing role of the HTS in terms of spending priorities.* • *The policy focus on knowledge exchange between industry and science has established a well-functioning innovation system, which still works too well to create momentum for rapid transformative change, e.g. in the automotive sector.*

Source: Rammer et al. (2022).

References

BMBF, BMWi, BMVI (2019). Aktionsplan Forschung für autonomes Fahren. Ein übergreifender Forschungsrahmen von BMBF, BMWi und BMVI. Berlin.

BMVI (2015). Strategy for Automated and Connected Driving: Remain a Lead Provider, Become a Lead Market, and Introduce Regular Operations. Berlin.

BMVI (2017), Bericht zum Stand der Umsetzung der Strategie automatisiertes und vernetztes Fahren. Berlin.

BMWi (2019), Case study and the Mittelstand 4.0 Competence Centres, Germany: Case study contribution on the OECD TIP Digital and Open Innovation project. Berlin.

BMWi (2020), The National Hydrogen Strategy. Berlin, Federal Ministry of Economic Affairs and Energy.
Federal Government of Germany (2020), Artificial Intelligence Strategy of the German Federal Government. 2020 Update. Berlin.

Legler, H., B. Gehrke, O. Krawczyk, U. Schasse, C. Rammer, N. Leheyda, W. Sofka (2009), Die Bedeutung der Automobilindustrie für die deutsche Volkswirtschaft im europäischen Kontext, Hannover and Mannheim: NIW and ZEW.

OECD (2022), OECD Reviews of Innovation Policy: Germany, OECD Publishing (will be published on October 4th, 2022).

Prodi, E, M. Tassinari, A. Ferrannini, L. Rubini (2022), Industry 4.0 policy from a sociotechnical perspective: The case of German competence centres, Technological Forecasting and Social Change, doi: 10.1016/j.techfore.2021.121341.

Rammer, C., R. Schmitz (2017), Fortentwicklung der EFI-Indikatorik: Förderlandschaft (Advancing the EFI Indicator System: Policy Support Activities), Studien zum deutschen Innovationssystem Nr. 9-2017, Berlin: Commission of Experts for Research and Innovation (EFI).

Rammer, C., D. Czarnitzki, A. Spielkamp (2009), Innovation Success of Non-R&D-Performers: Substituting Technology by Management in SMEs, Small Business Economics 33, 35-58.

Rammer, C., S. Daimer, R. Frietsch, H. Kroll, R. Walz (2022), Background Report for the OECD Review of Innovation Policy: Germany (unpublished document).

Som, O. (2012), Innovation Without R&D: Heterogeneous Innovation Patterns of Non-R&D-performing Firms in the German Manufacturing Industry, Berlin: Springer Science & Business Media.

Wietschel, L., Messmann, L., Thorenz, A., Tuma, A. (2021), Environmental benefits of large-scale second-generation bioethanol production in the EU: An integrated supply chain network optimization and life cycle assessment approach, Journal of Industrial Ecology, 25(3), 677-692.

Wydra, S. (2020), Measuring innovation in the bioeconomy – conceptual discussion and empirical experiences. Technology in Society 61, 101242.

About us

Cambridge Industrial Innovation Policy (CIIP) is a global, not-for-profit policy group based at the Institute for Manufacturing (IfM), University of Cambridge. CIIP works with governments and global organisations to promote industrial competitiveness and technological innovation. We offer new evidence, insights and tools based on the latest academic thinking and international best practices.

This report was delivered through the Babbage Forum.17 Charles Babbage Road, Cambridge, CB3 0FS, United Kingdom ciip.group.cam.ac.uk

UNIVERSITY OF CAMBRIDGE

BABBAGE FORUM

Cambridge Industrial Innovation Policy