6 Framework conditions for innovation in Germany

This chapter discusses the key framework conditions necessary for innovation in the German economy. These include the regulatory framework for innovation, digital and data infrastructure, as well as skills, education and labour market conditions. The chapter introduces recommendations on simplifying the operational environment for innovative firms through more effective digitalisation of government services and the adoption of more agile policy approaches. Although regulatory conditions for innovative firms in Germany are generally strong, there is scope for simplification. Similarly, despite Germany's well-educated population, the private sector faces a number of skill shortages and labour market rigidities that may affect its ability to perform innovative activities. With the growing importance of the digital economy and data-driven innovation, it is essential for Germany to invest in better digital and data infrastructures.

Introduction

Companies' ability to invest, experiment and innovate is shaped by framework conditions, including notably a well-functioning regulatory framework, access to capital, and an educated and skilled labour force. Moreover, with the digital transformation, connectivity and a high-quality data infrastructure are paramount.

Easing framework conditions and improving access to science, technology and innovation (STI)-related policy information – such as by reviewing the available support schemes – is particularly relevant for smaller players and start-ups. While framework conditions matter to all firms, smaller companies often have lower internal capacities to deal with business-environment and regulatory challenges, and therefore risk being disproportionately affected by framework conditions. Start-ups are also often at a disadvantage when it comes to accessing STI-related policy information and support programmes, as they lack prior experience.

Although framework conditions are important for incremental innovations, they are even more important to spur wide engagement of innovation actors in the disruptive innovation activities needed to support the green and digital transitions. The digital infrastructure, for instance, is essential to both transitions. Access to finance is necessary to invest in disruptive innovation, and the provision of funding to *Mittelstand* and start-up firms is therefore essential.

This section presents evidence on key framework conditions for innovation in Germany: the broader regulatory framework for business, access to finance for innovative firms, labour-market regulation and performance, skills, education, and the development of a digital and data infrastructure that can support innovation needs.

The chapter is split into five sections. Section 1 begins with a recommendation on improving the agility of policy making to support innovation. Section 2 considers the overall regulatory and legal framework for business. Section 3 reviews the digital and data infrastructure for innovators in Germany. Section 4 looks at labour-market conditions. Section 5 concludes with a discussion on skill capabilities and shortages in the German innovation system.

Recommendation 3: Broaden and mainstream the use of agile policy tools to support innovation efforts by SMEs, and achieve the digital and green transitions

Overview and detailed recommendations

The Federal Government should consider mainstreaming policy tools (such as regulatory sandboxes) to maximise their potential for change, normalise the use of such methods in the context of its approach to STI and generate more data for policy evaluation. Regulatory sandboxes (*Reallabore*) refer to a limited form of regulatory waiver or flexibility that enables firms to test innovative technologies, products or services which are not yet fully compliant with the existing regulatory framework. At the same time, the government should build greater flexibility into existing areas of regulation and policy, and adopt a more risk-taking and experimental approach to policy making in a context of important transformations.

R3.1 **Reduce bureaucratic and administrative barriers affecting SMEs and start-ups.** The government should both rationalise the processes required for certain government-to-business services, as well as the administrative steps required for firms to receive STI policy-support measures (such as innovation grants). Some SMEs and start-ups will shy away from applying for support schemes because the application procedures are not easily accessible or straightforward. Where legal barriers impede the simplification and flexibility of support measures, the government should undertake a review of the changes required to streamline access conditions. Programmes such as ZIM (BMWK) and KMU-innovative (BMBF) have demonstrated good practices and the feasibility of increasing the rate of firms participating for the first time in initiatives supporting research and innovation.

R3.2 **The government should pursue a programme of digitalising government policy, services and processes.** The digitalisation of government services should proceed after the rationalisation of existing regulations and procedures. Pivoting to digital delivery would consolidate all interactions between firms – particularly SMEs and start-ups – in a single location, preferably a digital "one-stop shop". More than digitising existing analogue processes, this requires improving them (by reducing the number of intermediary steps), and collecting and analysing data from interaction with digital services to further improve and inform policy making. The integration of new tools, such as machine learning and semantic analysis, could both improve the quality of government policy and regulation, and enable the government to take an active lead in the digital transformation of the public and private sectors.

R3.3 **Expand the use of regulatory sandboxes**. Germany's adoption of the Regulatory Sandbox Strategy (as discussed in Chapter 15 on policy agility and the corresponding R2 on the establishment of a policy laboratory) has been a decisive step in the use of regulatory sandboxes, but additional focus should be placed on the following:

- Strengthening regulatory co-operation across various federal regulators – as well as among municipal, state and federal authorities – when implementing regulatory sandboxes: this is particularly important because emerging innovative areas often cut across traditional industrial sectors, and thus the mandates of regulatory authorities and federal ministries.
- Targeting SMEs and start-ups to ensure they have access to regulatory sandboxes and that the eligibility criteria do not exclude younger or smaller firms: the government should continue to organise awareness-raising activities (such as competitions) on the opportunities and possibilities of sandboxes, with a particular focus on SMEs and citizens. Establishing regulatory sandboxes also requires avoiding possible regulatory capture by participating firms.

R3.4: **Support an easy-to-use digital one-stop-shop for STI policy engagement.** Germany currently provides the private sector with a wealth of policy instruments to support innovation, but

their overall effectiveness could be increased. To this end, the public administration should consider improving communication about these instruments, which currently includes a centrally co-ordinated platform listing the instruments, the Federal Funding Advisory Service (*Förderfinder des Bundes),* and individual consultation activities to allow firms to find offers matching their specific needs, the Federal Funding Advisory Service on Research and Innovation (*Förderberatung Forschung und Innovation des Bundes)*. Complementing these services with a full-fledged digital one-stop-shop for STI policy engagement of SMEs, start-ups and individual entrepreneurs would improve access and use of the support schemes. This digital one-stop-shop should also allow any firm (both domestic and international) to easily check its eligibility for different innovation-support instruments.. It would also integrate the existing consultation activities by centralising and digitising the back-office application processes for these instruments. The platform could also serve as a vessel for goal- and challenge-oriented innovation, increasing firm-level awareness of and participation in innovation programmes supporting socio-economic policy objectives.

Relevant global experience

Regulatory flexibilities

Digitally enabled products and emerging technologies often do not fit easily into existing regulatory frameworks, creating uncertainty for innovative firms. In addition, the pace of technological change, and the complexity of many of these technologies, create further challenges for regulators. Where digitally innovative firms face regulatory uncertainty – or even an absence of regulation – they may be disinclined to innovate, or unable to attract the funding necessary for innovation and business scaling. Recognising this issue, policy makers across the OECD have begun to experiment with their approaches to regulation, several countries moving towards a “test-and-learn” approach to regulating.

One of the most commonly used approaches – including in Germany – is regulatory sandboxes, a limited form of regulatory waiver or flexibility that enables firms to test new business models or products with reduced regulatory requirements. Sandbox approaches are useful for advancing German innovation in key industries (such as autonomous driving for the automotive industry), but also for achieving the green transformation of industry.

Two interesting examples that utilise sandboxes for green transitions are the United Kingdom’s “Innovation Link” and France’s “Experimentation”. The UK energy regulator Ofgem launched a regulatory sandbox called “Innovation Link” for innovators in the energy sector, which enables them to trial innovative business products, services and new business models that could not operate under existing regulatory conditions (Attrey, Lesher and Lomax, 2020[1]). The inspiration for the Ofgem sandbox came from software development, where it is common to test new code in a controlled setting without risking the integrity of the wider programme. The programme involves bespoke guidance for programme participants, and projects included peer-to-peer energy trading and innovative tariff systems. The experience of France’s “Experimentation” also highlighted the potential for sandboxes to support sustainability objectives, with a quarter of the 85 applications to its industrially and technologically agnostic programme focusing on environmental protection (Attrey, Lesher and Lomax, 2020[1]).

Regulatory flexibility also has an important role to play in supporting the digital transformation of the economy (OECD/KDI, 2021[2]). This is particularly true in the context of digital service platforms, which often blur the boundaries between sectors and industries (including banking), creating new regulatory challenges. The question of data regulation, which remains a complicated issue in the German context owing to the decentralised nature of data governance in the country, is particularly salient here. In 2016, the UK Financial Conduct Authority launched a regulatory sandbox programme that allowed businesses of all sizes to test innovative financial products in the market with real consumers. The programme

objectives included allowing firms to test potentially disruptive products in a controlled environment, to reduce the time to market of commercially viable products and business models, and to identify consumer protection gaps in existing regulation related to these new products. Similar programmes have since been launched in a number of OECD countries, including Canada, where the Canadian Securities Administrators conducted a programme in 2016-19 to support finance and technology (fintech) firms through time-bound regulatory waivers to gain a better understanding of how innovations could affect financial markets (OECD/KDI, 2021[2]).

While many OECD countries have now begun to address issues of regulatory agility, these approaches remain mostly industry-specific. This is understandable, as many of these programmes are administered by domain-specific regulators. Mainstreaming these approaches in Germany – and monitoring their implementation under, for example, the policy forum suggested in Recommendation 1 or the policy laboratory discussed in Recommendation 2 – would offer the advantage of adding a greater level of directionality to these efforts, guiding them towards whole-of-economy transformational goals.

Agility is also important in the policy-making process itself. A range of new digital tools can enable policy makers to make better-informed decisions more quickly and efficiently. As discussed in the TIP report '*Alternative Tools to Support Innovation Policy: What is Feasible Today'*, a range of digital tools are becoming available to support policymakers and enable them to be more agile in their approaches to policymaking. These tools can support more granular and timely data collection (e.g. pulse surveys or web-scraping), more effective processing of evidence and data (for example, by using semantic analysis on textual data, natural language processing and artificial intelligence), as well as improve societal participation STI and STI policymaking (e.g. online and participatory digital platforms) – the importance of which will continue to grow in the transitional context.

Mission-oriented innovation policies

Mission-oriented policies are defined as a co-ordinated package of policy and regulatory measures tailored specifically to mobilise science, technology and innovation in order to address well-defined objectives related to a societal challenge over a defined period of time (Larrue, 2020[3]). These measures can span different stages of the innovation cycle, from research to demonstration and market deployment, supply-side and demand-side instruments, and cut across different policy fields, sectors and disciplines.

Mission-oriented innovation policies (MOIPs) in France belong to a long tradition of proactive policies to achieve strategic or economic objectives or, more recently, to respond to major societal challenges. These include in particular the Grands Programmes, the 'Thematic research networks' (Réseaux thématiques de recherche) such as PREDIT during fifteen years to support research for the automobile industry since the beginning of the 1990s, as well as the large-scale projects of the Industrial Innovation Agency (Agence de l'innovation industrielle) in the mid-2000s. The initiatives aimed at supporting a more strategic approach and allowing critical mass on national priority areas and projects in a policy landscape largely characterised has fragmented and multi-layered.

The fourth generation of the Future Investment Program (PIA4) launched in 2021 may mark a turning point. It is structured in two main so-called "intervention logics". The "structural logic" provides long-term sustainable funding to key research and innovation institutions. The "directed logic" promotes a more directional approach to support exceptional investments to meet 5 "Grand Challenges" (1. Securing, certification and reliability of artificial intelligence; 2. Improving medical diagnostics through artificial intelligence; 3. Cyber-security: making our systems sustainable resilient to cyber-attacks; 4. Producing high value-added proteins biologically and at a reduced cost; 5. Development of high density energy storage for sustainable mobility.) These challenges were selected by the Innovation Council, created in 2018 to define the main priority orientations of the French innovation policy, define cross-cutting actions and simplify the French research and innovation policy landscape.

The main instruments of the 'Directed logic' component are the Acceleration Strategies. In specific challenge areas, these large initiatives aim to identify the main socio-economic transition challenges and to invest to tackle these challenges using a global and systemic approach combining various modes of intervention (research, training, financing, standards and norms, taxation, etc.). The expected added value of Acceleration Strategies is not primarily in the novelty of the supported activities but in their stronger strategic steering and integration along the innovation cycle. While the objectives of the first PIA were politically determined in 2010 in the context of the 2008 financial crisis, the PIA4's acceleration strategies are co-constructed by all relevant partners. For instance the "Digital Health" acceleration strategy resulted from a public consultation A dedicated working group of the Digital Health Council (CNS) on "economic development of digital health / structuring of the sector" also provided inputs for the preparation of the strategy. Each Strategy also has specific targets.

For instance the carbon-free hydrogen acceleration strategy has set targets for 2030, including the installation of a carbon-free hydrogen production capacity of 6.5 GW by electrolysis, the saving of more than 6 Mt of CO2 and the creation of 50,000 to 150,000 direct and indirect jobs in France. Each strategy has its own structure of governance, with a dedicated interministerial coordinator who report to the Innovation Council. The task of the coordinator is to lead the interministerial coordination and monitoring of all the actions implemented. The Carbon free Hydrogen Acceleration Strategy has a budget of EUR 3.4 billion during the period 2020-2023, and EUR 7 billion are planned until 2030. The Strategy covers all aspects related to the establishment of a hydrogen value chain (filière) from research to production, pipelines and markets. The Acceleration Strategy also aims to develop key technologies and components through pilot projects for different types of usages and markets.

Other countries have set up more integrated and focused missions at a lower level in their innovation systems, notably under the leadership of one or several agencies. In Norway, three agencies have set up 'Pilot-E', a joint initiative to serve as a one-stop-shop that provides seamless support from idea to market to various climate emission free and energy saving solutions. Within this cross-agency scheme, the three agencies mobilise their respective instrument portfolio to support jointly selected projects to reach collective goals with the aim to both initiate the necessary energy transition and develop new business activities.

Another type of mission-oriented policy, popular in Nordic countries, mainly relies on ecosystems. These initiatives aim at creating and structuring national or regional innovation ecosystems (bringing together public and private stakeholders from different research and business communities), around a common challenge. This model generally operates in two stages: 1) A call for roadmaps where public authorities provide incentives for the development of roadmaps proposed by ecosystems (established or emergent) to solve societal and economic challenges; 2) selection, engineering (e.g. mergers, reorientations) and support to the implementation of roadmaps, using the underpinning ecosystem to coordinate actions. This is the case of the Strategic Innovation Programme (SIP) led by the Swedish innovation agency Vinnova, the Finnish Growth Engines and the Danish Green Missions. This approach allows stronger directionality and legitimacy by delegating responsibilities related to strategic orientation and coordination to relevant community (ecosystems) of stakeholders in priority or emerging areas.

6.1. The regulatory framework for innovation and access to innovation policy: Information and support programmes

The regulatory framework for business refers to the legal conditions for a firm's operations and affects all aspects of the business life cycle, including starting and closing a firm, accessing finance and exporting products. The regulatory framework interacts with the innovation system in several ways:

- Regulatory frameworks create legal stability which allows firms (both domestic and international) to make decisions on innovation investments.

- They also add costs to innovation, ranging from costs associated with opening an innovative business to obtaining approval for selling a new product.
- Finally – and particularly salient to innovation in emerging technological areas – the regulatory framework can give clarity, or create a lack of clarity, for innovators working on products and services at the technological frontier.

These aspects of the regulatory framework for firms occur in an environment that is dynamic and interacting with other economies and jurisdictions around the world, particularly the European Union. Consequently, the "ease of doing business" will also affect in which country international innovative activities are taking place.

A key challenge for policy makers and regulators is how to design governance strategies and regulations that prevent or mitigate the unintended and unknown negative consequences of scientific and technological developments, without stifling innovation and while harnessing the opportunities stemming from such advances. Laws and regulations also allow governments to influence the development of innovations and direct them towards the benefit of society, as well as minimising risks.

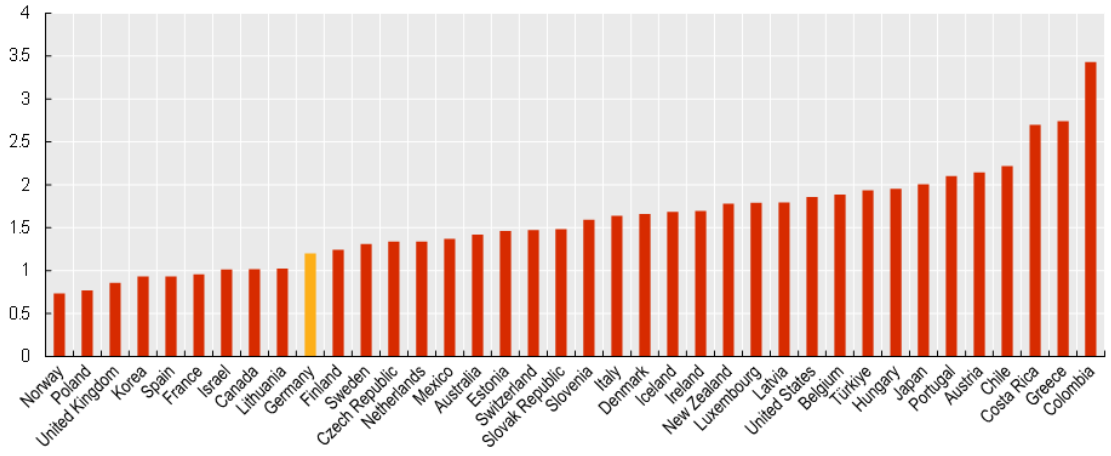
In addition to the general regulatory framework for business in Germany, policy makers face a number of key regulatory questions regarding innovation, particularly in the context of the green and digital transitions. What can be done to facilitate administrative framework conditions and access to policy information and support programmes for stakeholders in the STI ecosystem, particularly *Mittelstand* and start-up firms? How can policy makers advance innovation, reconciling the need for agility and flexibility in innovation regulation with the need for stability and predictability?

6.1.1. The regulatory environment for firms in Germany is generally strong, but a number of issues may weigh on the innovative capacities of firms

The quality of business regulations in Germany is generally high, and administrative barriers to entrepreneurship are low (Figure 6.1). Recent reforms, such as the introduction of a "one-in-one-out" rule for regulation offsetting – whereby regulators must abolish one regulation for every new one introduced within a year of the introduction of the new rule – has helped simply the regulatory environment for business (Trnka and Thuerer, 2019[4]). The third version of the *Bürokratieentlastungsgesetz* (the Law on reducing bureaucracy, introduced in 2015 as part of the "Bureaucracy Reduction and Better Regulation" programme) further lowered regulatory burdens for firms, creating an estimated EUR 1.1 billion (euros) saving for the private sector.

Figure 6.1. OECD Product Market Regulations: Simplification and Evaluation of Regulations (2018)

Germany is among the top OECD performers in terms of the simplification of business regulation



Note: The indicator is on a scale of 0 (least burdensome) to 6 (most burdensome), with the indicator established following a detailed questionnaire issued to the country in question
Source: OECD (2022[5]) "Economy-wide regulation", OECD Product Market Regulation Statistics (database), https://doi.org/10.1787/data-00593-en (accessed on 24 May 2022).

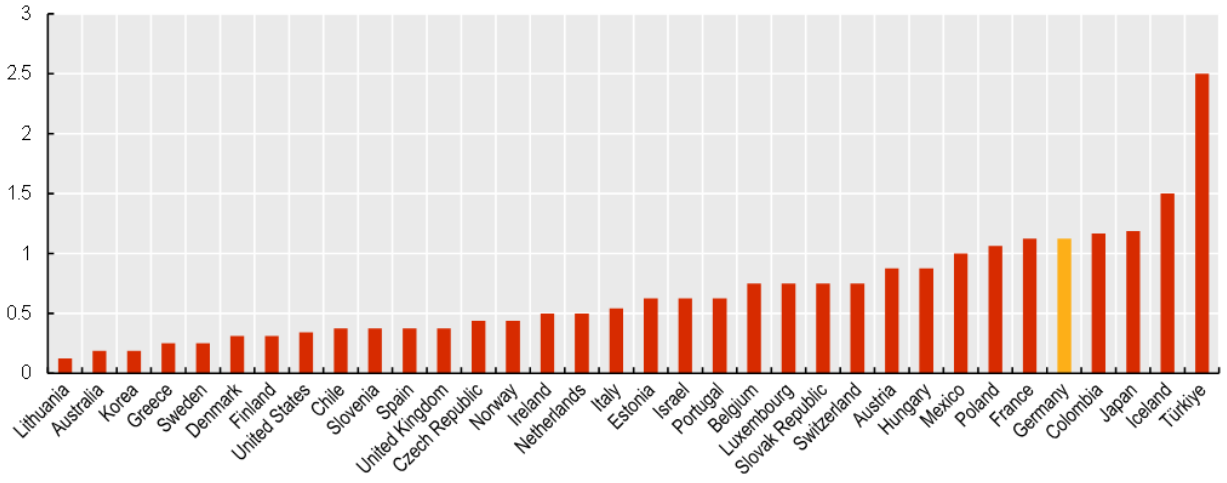
However, there exist opportunities for improvement: starting and closing a business in Germany is more difficult than in other OECD countries owing to lengthy and costly administrative procedures, many of which are only partly digitised. Administrative burdens for start-ups remain markedly above the OECD average (Figure 6.2). For example, starting a business in Germany requires entrepreneurs to make appointments with various administrative bodies, with the associated paperwork often remaining entirely analogue. This lack of digitalisation and consolidation stands in marked contrast to many OECD countries, where digital "one-stop-shops" for enterprise creation have been established.

While extensive information on Germany's many innovation-support instruments is available on the individual programme and institutional websites, identifying the most suitable support poses a challenge for smaller firms and start-ups in particular. Application procedures can also be complex, particularly if the documentation required varies strongly across programmes. In a 2021 survey conducted by BMWK during the COVID-19 pandemic, 89% of participating SMEs agreed that application processes for innovation-support measures should be both reduced and accelerated (BMWi, 2021[6]).

One action that might help reduce the administrative burdens and costs for firms would be to further pursue the digitalisation of public services. According to the OECD Digital Government Index, Germany currently scores the lowest among all OECD countries in the data-driven public-sector dimension. Better data-sharing across public services could significantly reduce the burden on firms using government services as it would limit the need to submit the same information multiple times to different public bodies (OECD, 2021[7]). An important step in this direction is the Online Access Law (*Onlinezugangsgesetz*) introduced in 2017, which requires public authorities at the federal, regional and local levels to make a range of administrative services digitally available by 2022.

Figure 6.2. Administrative burdens for limited liability companies and personally owned enterprises are high

Countries ranked in ascending order, from most (0) to least (6) competition-friendly



Note: For federal countries, where matters are regulated at state level, the values reflect the situation in one selected representative state (listed below).
Source: OECD (2022[5]) , "Economy-wide regulation", OECD Product Market Regulation Statistics (database), https://doi.org/10.1787/data-00593-en (accessed on 24 May 2022).

Identifying where regulatory requirements for firms can be eased without compromising consumer safety will also be important. The 323 new regulations – often related to information technology (IT) – introduced between 2011 and 2019 created over EUR 12 billion in one-off compliance costs for firms; only 51 of these regulations reduced ongoing costs for the economy (NKR, 2019[8]).

6.1.2. Anticipating and preparing for sustainable and digital transition changes: New approaches to regulatory flexibility

The sustainability and digital transitions require disruptive changes and products, while at the same time providing the necessary security to consumers. The regulatory environment for innovators needs to be flexible or future-proofed to keep up with rapid advances in technologies. In the context of digitalisation and emerging technologies, the rate of change often exceeds the speed with which regulators can react, and new technologies and their applications – particularly where previously separate technologies and industries begin to intersect – can lead to a level of uncertainty that is difficult to codify in laws and regulations. The popular regulatory sandboxes permit a degree of legal and regulatory flexibility in certain technology fields or industries, with the aim of developing and commercialising new innovations. These initiatives can be organised at the national, federal or city level, and oriented towards missions or goals. A key aspect of German regulatory sandbox policy is the notion of “experimentation clauses” (*Experimentierklauseln*). These are legal provisions that allow implementing authorities to exercise case-by-case discretion in applying the rules. The clauses generally have one of two objectives: to create opportunities to test innovations where the existing legal framework does not permit the proposed application; or to allow regulators and legislators to learn at an early stage about new technologies, and adapt the legal framework accordingly. BMWK has been implementing a cross-governmental sandbox strategy to ease the regulatory conditions for sandboxes since 2018. It recently proposed a concept for a regulatory sandbox law that would codify standards for experimentation clauses and review existing ones.

The law would be complemented by a "one-stop-shop" for sandboxes as a central entity charged with reviewing experimentation clauses.

The BMWK, and the government more broadly, are open to using flexible and anticipatory regulation to support innovation. As with other areas of innovative public policy, the challenge is mainstreaming these approaches throughout government; supporting their more holistic and strategic use; and ensuring that civil servants and public officials, as well as private-sector counterparts, are aware of the opportunities available to them and are encouraged to utilise these tools. The Federal Government has been making inroads in these areas. As early as 2015, it started establishing sector- and technology-specific programmes, like the Digital Motorway Test Bed for autonomous driving. While these individual programmes are impressive, the different initiatives lack interconnectedness, limiting the ability of these islands of regulatory flexibility to contribute to broader – and strategic – government ambitions.

An important area of regulatory consideration for innovative firms, particularly those engaged in advanced information and communication technology (ICT) and data, is regulation surrounding the use of AI. In Germany, as in other jurisdictions, the suitability of extant regulation and standards, as well as the complexity of processes involved with AI and ML, pose challenges. A key example is the notion of "explainability" in AI processes – i.e. the ability to describe and explain how an AI process reaches a decision – which regulators continue to require regulators at the national and EU levels. Regulators' attachment to explainability is understandable – particularly in the context of sensitive applications, such as in medicine– but deriving the working processes for decisions and outcomes from the neural networks that underpin more advanced AI is increasingly difficult, if not impossible.

Managing this tension in a regulatory framework is likely to become an increasingly important area for policy makers. Getting it right will be important to ensure that Germany and the European Union are desirable locations for AI-based innovation in the future. To this end, it is notable that the European Union has developed a number of documents exploring the issues of regulation in AI, such as the 2020 *White Paper on Artificial Intelligence* and the Joint Research Council's *Technical Report on Robustness and Explainability in Artificial Intelligence* (Hamon, Junklewitz and Sanchez, 2020[9]; European Commission, 2020[10]). At a national level, Germany has explored issues of explainability in AI through standardisation institutions such as Deutsches Institut für Normung (DIN), which in 2020 released the *German Standardization Roadmap on Artificial Intelligence* (Wahlster and Winterhalter, 2020[11]). While these endeavours demonstrate advanced thinking on the ways in which AI should – and could – interact with the innovation system, they nevertheless represent an attempt to codify ex ante the limits of a technology that is still at a relatively early stage of development.

6.1.3. Data regulation

Data are another area of German regulation with particular impacts on innovation. The role of data regulation and innovation is complex and multifaceted, with the OECD issuance a Recommendation on Enhancing Access to and Sharing of Data in 2021 reflecting the importance of this issue on the global policy agenda (OECD, 2021[12]; OECD, 2015[13]; Guellec and Paunov, 2018[14]). A number of existing regulatory barriers in the collection and use of data affect the ability of German firms to make the most of opportunities in the context of Industry 4.0, as well as the ability of the German economy to support and grow data-driven firms in the service sectors. Of course, data regulations also have international dimensions: data regulation and compliance may yield market-creating opportunities, but they also impose regulatory hurdles that discourage some firms from engaging in innovation in this field (Casalini, López-González and Nemoto, 2021[15]).

Data-privacy regulations at the national and EU levels also affect the use of private data. Within Germany, compliance with data regulation is complicated by regulatory fragmentation, since the country has 18 separate regional bodies for data regulation. A recent survey of a representative sample of 502 firms conducted by Bitkom (the German industrial association of firms in the digital economy) found that

compliance with German data regulation continues to significantly raise costs for firms, and that the quality of support from regulatory bodies was insufficient (Weiß and Streim, 2021[16]). The EU General Data Protection Regulation (GDPR) was introduced by the European Commission in 2018 to harmonise privacy laws across the European Market for all firms operating in the EU market. Respondents to the Bitkom survey reported increased compliance costs since the introduction of the GDPR. Yet there is also evidence that the GDPR has generated opportunities for innovation by providing a more harmonised regulatory framework, facilitating firms' compliance (Martin et al., 2019[17]). In addition, the GDPR has helped mainstream data-privacy considerations, which are an essential element to build consumer trust in data-based business models.

6.2. Broadband and data infrastructure for innovation

Reliable infrastructure – including better-quality broadband or cellular networks, in addition to traditional areas of "hard' infrastructure" – is a prerequisite for innovation and employing innovative approaches to work. At the same time, innovation *in* infrastructure development is just as important, particularly when considering the role of public infrastructure in climate resilience or infrastructure to support industrial decarbonisation (covered in Chapter 11).

Data are an increasingly important input for innovation and play an essential role in three key ways:

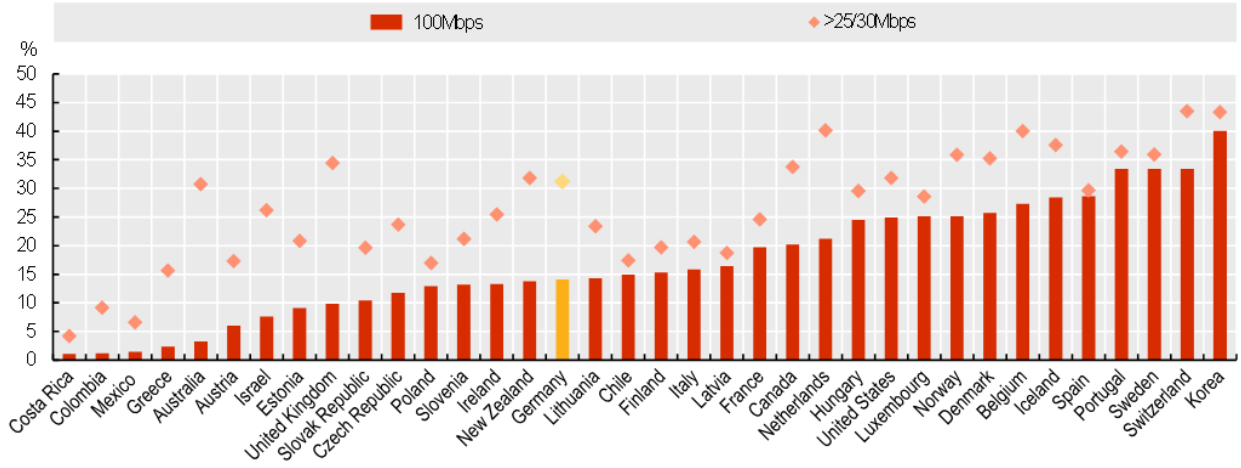
- First, exploiting data from production, logistics and research allows firms to innovate value chains, improve the efficiency of energy use and other inputs. In turn, digitising these processes produces further data that can be used as input for innovations.
- Second, business data can help inform decision-making on smart grid technologies and decarbonisation processes. Data produced through business operations are therefore integral to the sustainability transition.
- Third, the digitalisation of the public sector will allow policy makers to use more powerful tools to design policy interventions, map scenarios and exercise foresight, as well as help boost public services relevant to innovative businesses.

This section considers the state of digital connectivity underpinning the potential roles of data in supporting Germany's innovation system and its transition objectives.

The latest OECD Economic Review of Germany outlined the digital infrastructure challenges Germany faced in expanding access to high-quality broadband infrastructure; such shortcomings affected Germany during the COVID-19 pandemic (OECD, 2020[18]). Relatively low levels of digital connectivity, particularly in terms of fixed high-speed broadband networks (Figure 6.3), limit the economic and innovative potential of digitalisation. They can also deepen inequalities – as in Germany, which is characterised by a significant rural-urban connectivity divide. In 2019, 94% of households in large cities had access to fixed broadband with download speeds of over 100 Megabits per second (Mbps), compared to only 53% of households in rural municipalities (OECD, 2020[18]). The adoption of ICT tools – ranging from simpler processes such as enterprise resource planning and customer relationship management, to more complex applications such as big data analysis, social media and cloud computing – may be affected by limited high-speed broadband (OECD, 2021[19]). These supply-side issues may also have a demand-side impact for new, data-rich and technologically intensive services, as the ability of households and firms to take advantage of such services will be impeded by connectivity barriers. These demand-side barriers are perhaps one explanation for firms' persistently low uptake of data-heavy and advanced ICT tools, as discussed above.

Figure 6.3. Germany has a low share of internet subscriptions in higher-speed tiers (2020)

Fixed broadband subscriptions with contracted speed faster than 25/30 Mbps and 100 Mbps, June 2021



Note: Denmark: Data are temporary OECD estimates, Switzerland: Data are preliminary; Based on 2020 speed tiers.
Source: OECD (2022[20]) Broadband Portal, https://www.oecd.org/sti/broadband/oecdbroadbandportal.htm.

In 2020, Germany numbered 44 fixed broadband subscriptions per 100 inhabitants, higher than the OECD average of 33. However, the share of subscriptions in higher-speed tiers – which are crucial for using key ICT tools, such as cloud computing and data processing – is low. The vast majority of fixed broadband subscriptions are digital subscriber line (DSL) technology, indicative of the low percentage of higher speeds shown in Figure 6.3; fibre optic connections for households account for only 4.1% of the broadband mix, significantly below the OECD average of 28%. Access to high-speed broadband is also heavily region-dependent (Figure 6.4), which may create or exacerbate digital divides between SMEs and entrepreneurs across the country. The regionality of the connectivity divide also highlights the importance of ensuring that municipal authorities can disburse funds set aside at the federal level to upgrade their connectivity infrastructure, an objective that is sometimes hindered more by administrative barriers than by the availability of funds for investment (OECD, 2020[18]). Given that DSL technology, which remains prevalent in many rural areas, was designed for low-speed analogue voice services, these connections suffer from an inherently asymmetrical capacity and are largely unsuitable for many modern ICT and data-intensive activities. The demand for better services is clear, and Germany's firms would likely capitalise on increased access to better-quality connectivity, leading to productivity gains and the opportunity to pursue hitherto impossible innovation activities.

Figure 6.4. Access to high-speed fixed broadband is geographically dependent

A. Coverage > 30Mbps

B. Coverage > 100Mbps

Note: Pale blue – 10-50% of households, blue 50-75%, dark blue 75-95%.
Source: MIG (2021[21]), *Breitbandatlas*, https://netzda-mig.de/breitbandatlas/interaktive-karte (accessed on 1 April 2022).

A key pillar of the German economy's digital transformation is the expansion of 5G in the country. Progress has been made in this area (though there remains a lack of consensus internationally on how to benchmark 5G rollout), with the German Federal Network Agency reporting in December 2021 that 53% of the country's territory – around 80% of the population – is now covered with at least one 5G network provider (BNetzA, 2021[22]). The expansion of the 5G network is an important framework condition for the Industry 4.0 programme of the BMWK, which looks to help the private sector to embed digital and advanced technologies into production processes, with a view to increasing productivity and efficiency. For example, the authors of a 2020 study by the German market intelligence firm International Data Corporation (IDC) found that 59% of the 254 sample firms surveyed across five sectors of the economy intended to implement industrial internet of things projects – a key component of Industry 4.0 – using 5G technology (IDC, 2020[23]). Importantly, fibre optic internet and wifi are equally valid ways of powering IoT.

The example of 5G, and its importance to the digital transformation of the private sector, highlights the need for investing in the infrastructure underpinning these transformations. Beyond the general connectivity infrastructure, this extends into the service-based infrastructures that depend upon it, such as cloud computing and data infrastructures. Cloud-based computing and data storage are important for internet of things applications such as predictive maintenance analysis, yet German firms significantly lag behind the best-performing OECD countries in adopting these applications, as discussed in Chapter 10 of this review.

6.3. Labour market conditions

6.3.1. Employment regulation and the labour market

Labour markets interact with innovation by allowing firms to find and hire workers with the skills necessary for innovation, which in turn supports the diffusion of new technological knowledge through the economy. Germany has a historically strong performance in ensuring labour-market entrants are equipped with the skills and technical knowledge necessary to succeed in some of the country's leading innovative sectors. The challenge in the years ahead will be to ensure that as the types of skill and knowledge required change (owing for example to a greater focus on digital and ICT skills over mechanical ones), the policy programmes and institutions that both train and match workers to companies adapt to new demands.

Employment protection is generally high in Germany, which has the seventh-highest employment protection for individual and collective dismissals in the OECD (OECD, 2019[24]). Skill levels do not generally make a difference in hiring or firing conditions (OECD, 2019[25]). According to a study by Muehlemann and Pfeifer (2016[26]), the cost of hiring skilled workers in Germany is eight weeks of pay on average and increases with firm size. In a 2017 survey of 12 775 business executives (112 from Germany) across 137 countries, Germany ranked 18th in terms of flexibility of hiring and firing conditions – numerically above average, with a score of 4.66 on a scale from 1 (heavily impeded by regulation) to 7 (very flexible). Germany was more flexible than Italy (3), Japan (3.5), Korea (3.54) and France (3.67), but more regulated than the United Kingdom (4.99) and the United States (5.31) (World Economic Forum, 2018[27]).

6.3.2. Labour market performance during the COVID-19 period

The German labour market remained relatively resilient to the COVID-19 pandemic, from its onset in March 2020 to March 2022, with modest employment losses compared to other OECD countries. This partly reflects the strengths of Germany's short-time work (STW) scheme (*Kurzarbeit*), where employers reduce employees' working hours instead of laying them off. Other OECD countries also relied heavily on STW during the COVID-19 crisis. Germany had previously used the STW work scheme for job retention during the global financial crisis, where it was however far more widespread in the manufacturing sector, unlike during the pandemic, where some 80% of STW applications were in services (OECD, 2021[19]).

In May 2021, the seasonally adjusted unemployment rate in Germany was 3.7%, the fourth-lowest in the OECD. This level was only 0.2 percentage points above its value at the beginning of the crisis and 0.4 percentage points below the peak during the pandemic; these increases were significantly lower than in other OECD economies, such as the United States and Canada (OECD, 2021[28]). Germany's level of youth unemployment is higher (8% in May 2021), although still the fourth-lowest in the OECD, and only marginally above the pre-pandemic rate. However, as in other OECD countries, the COVID-19 pandemic has had a multifaceted impact on Germany's labour market, specifically with regards to training opportunities and the reallocation of labour market participants that was challenged during the COVID-19 crisis.

The relatively low level of adoption of digital tools in the workplace and at home also illustrates resilience and agility challenges in the German context. Throughout the pandemic, Germany relied much less on teleworking than comparable OECD countries. This was also true prior to the pandemic, when only 10% of employees in Germany worked from home occasionally, compared to 18% in France, and over 20% in the United Kingdom and the United States. During the crisis, the number of employees working from home tripled (to 31%) in Germany, but nevertheless remained below France (33%), and significantly below the United Kingdom and United States (around 50% each) (OECD, 2021[28]). The uptake of teleworking arrangements in Germany depends strongly on employees' educational attainment. College graduates are twice as likely to have worked from home during the pandemic than employees who did not go beyond secondary education, and are nearly five times more likely to work from home than workers with no high

school degree. Workers in the top 25% of the earnings distribution are over 50% more likely to telework than workers in the bottom 25% of the earnings distribution.

6.4. Germany's skill base and capabilities for innovation

6.4.1. Overview of the supply of skills and capabilities for innovation

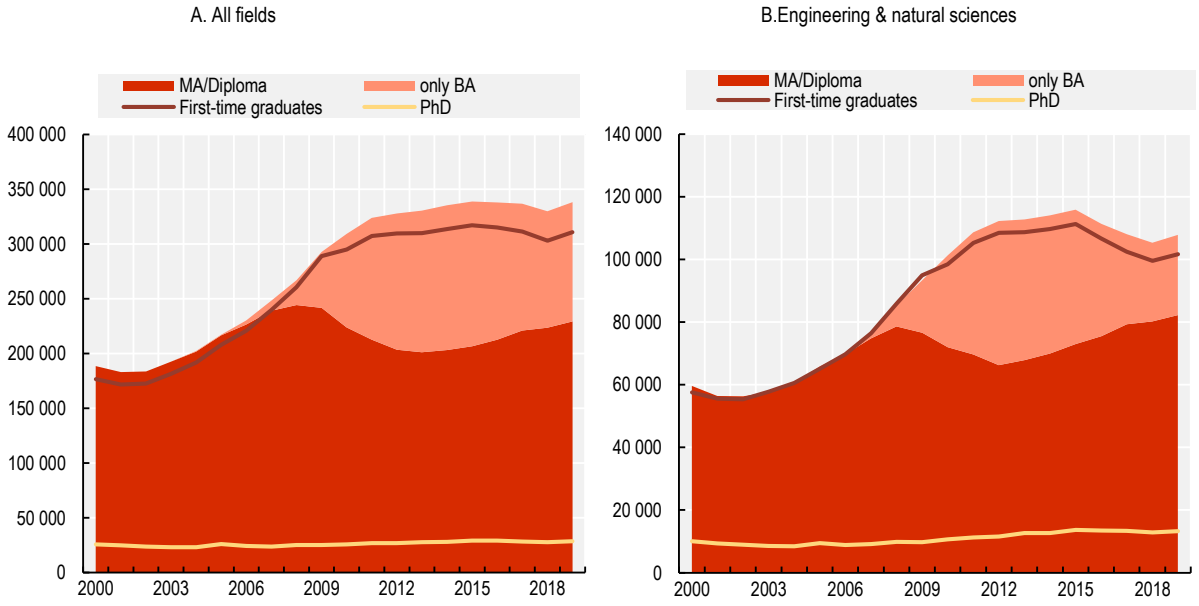
Germany's innovation system is supported by a well-educated and highly skilled workforce, with a strong increase in the share of entrants in tertiary education in the past two decades. Although below the OECD average (44%), 32% of young adults (aged 25-34) in Germany held a tertiary degree in 2018, compared to 24% in 2008. The share of higher education graduates in the total population of the same age expanded from about 17% in the early 2000s to 32% in 2019, and has been continuing at this rate ever since (OECD, 2019[29]).

The increase in the number of higher education graduates in Germany began in 2002 and accelerated after the shift from diploma-based curricula to a Bachelor of Arts (BA)/Master of Arts (MA) system in 2009. The number of first-time graduates was at its lowest in 2001 (172 000). It then grew steadily year by year, peaking at 317 000 in 2015 thanks to the new BA/MA system, which produced a growing number of BAs who did not pursue an MA programme. The number of graduates with a diploma or master's degree peaked in 2008 (244 000) and declined until 2013 (201 000), slightly increasing thereafter (229 000 in 2019).

Evidence from private-sector job openings suggest that most firms are still looking for MA degrees to fill vacancies requiring academic skills. While the federal and state governments initially expected only a fraction of BA graduates to pursue a master's degree, around 90% of BA graduates from the general and technical universities embark on an MA programme. The share is markedly smaller (about 40%) at universities of applied sciences (*Fachhochschulen*) (DIPF, 2020[30]). As a result, the share of graduates with "only" a BA in the total number of graduates is declining, particularly in engineering and natural sciences (including mathematics and computer sciences), which is particularly relevant for suppling high-skilled labour for innovative firms. The number of new PhD graduates also grew in this field, from under 9 000 in 2006 to over 13 000 in 2015.

Graduates in science, technology, engineering and mathematics (STEM) disciplines are particularly relevant to innovation in firms. Over the past two decades, the number of MA and PhD graduates in these fields has increased faster than the total number of graduates (Figure 6.5). The share of MA graduates in STEM fields rose from 30% in 2005 to 36% in 2019. The increase was even more marked for PhD graduates, from 36% in 2005 to 46% in 2019. According to data from the OECD Education Database, the share of university STEM graduates in Germany is higher than in almost all other comparator countries, except Japan (OECD, 2021[31]). Moreover, the number of MA and PhD graduates in STEM fields has been increasing faster than the total number of graduates. STEM graduates are particularly key for addressing new technological and societal challenges, as well as industrial innovation needs.

Figure 6.5. Number of graduates from higher education in Germany (2000-19)



Source: OECD calculations based on data from Destatis (2022[32])

The supply of new graduates with such skills has been quite stable in absolute figures over the past ten years. Every year, Germany numbers about 16 000 first-time graduates in IT-related higher education fields, and between 10 000 and 12 000 graduates having passed exams in vocational training related to IT occupations. Between the early 2000s and 2009, the number of first-time university graduates in IT-related fields grew strongly in response to a significant shortage of related skills during the "new economy boom" in the late 1990s. The pool of IT graduates will likely increase in the coming years, both in higher education and vocational training, as the number of first-year students is growing – probably due to heightened public attention towards digitalisation. With the transition from diplomas to a BA/MA system, the number of graduates with an IT-related diploma or MA significantly decreased, from 14 000 in 2007 to under 8 000 in 2014, particularly because many students at universities of applied sciences did not go on to pursue an MA programme. The figure has increased since then.

Germany also scores high in international rankings in terms of doctorates and the placement of scientists in the business sector. Roughly 29 000 graduate students complete a doctorate in Germany every year, more than half of which are PhDs in natural sciences, mathematics and engineering. These figures are far higher than in any other EU Member State. In total, Germany's share of population with a doctoral degree (1.6% in 2020) is above the OECD average (1.3%) and similar to that of Australia, Norway and the United Kingdom, but lower than the United States (2.0%) and leading countries like Switzerland (3.0%) or Slovenia (5.2%) (OECD, 2021[33]).

The below-average share of university graduates in Germany is compensated by – and likely due to – its highly developed and widely respected vocational education and training (VET) system, which integrates both learning in vocational schools and training in the workplace. More than 50% of adults aged 25-64 and 40.8% of those aged 25-36 received a vocational upper-secondary or post-secondary qualification in 2019. Over the past decades, the VET system has played an important role in expanding the skills and capacities of the German workforce. At the advanced tertiary level, attainment is among the highest in the OECD: 1.6% of 25-64 year-olds have graduated from a doctoral or equivalent programme (eighth-highest rank in the OECD) and 2.1% of adults under 35 (third-highest) (OECD, 2021[34]). However, the supply of workers with VET degrees related to manufacturing, handicraft and professional services has declined by 19% in

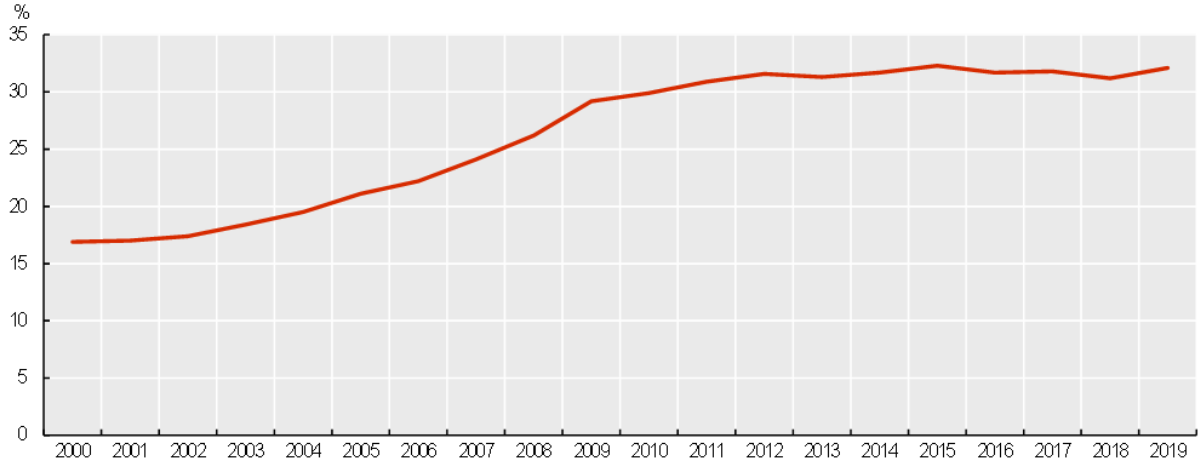
Germany, from 444 000 in 2005 to 359 000 in 2019. By contrast, the number of first-time graduates from higher education rose by 49%, from 208 000 in 2005 to 311 000 in 2019.

Moreover, Germans do well in soft skills by international comparison. German adults perform above the OECD average in key information-processing skills (see the 2018 Survey of Adult Skills [PIAAC]) (OECD, 2019[35]). According to the PIAAC data, Germany performed relatively well in building foundation skills, the average literacy achievement of students at age 15 increased more than the OECD average between 2000 and 2018.

6.4.2. Opportunities and challenges for the skill base and capabilities in Germany

It should be noted that the expansion in the supply of academically trained people in Germany over the past two decades occurred at a time when demographic change caused a decline in the number of young people (Figure 6.6). This implies that the share of higher education graduates in the total population of the same age sharply increased, from about 17% in the early 2000s to 32% in 2019. The increase mainly took place between 2002 and 2012, while little positive dynamics have occurred over the past seven years. This will further complicate the challenge of providing the required skill base.

Figure 6.6. Share of first-time higher education graduates in the total population of the same age in Germany (2000-19)



Source: OECD calculations based on data from Destatis (2022[36])

There exist opportunities to expand Germany's skill and capability base by increasing diversity. Currently, two out of every three tertiary graduates in STEM are men, perpetuating the under-representation of women in key innovation sectors. Attracting and encouraging individuals from under-represented groups, including students from non-academic and minority households, to engage in innovation should be one component of a strategy to address skill shortages, as discussed in Chapter 15 on inclusivity.

Germany's traditional institutional organisation of public-private co-ordination and co-operation, which has supplied skills suited to the needs of its successful innovation system, now needs to be exploited in a new context. The Humboldtian university model, which has historically emphasised research, knowledge generation and intellectual inquiry, together with the focus of Germany's well-regarded technical universities on engineering and applied sciences, have contributed to the rich supply of well-educated labour-market entrants. The close collaboration between industry and academia in German educational institutions has ensured that the skills of individuals entering the industrial sectors are suited to innovation and practical application.

6.4.3. Skill shortages and their consequences for innovation

Despite the good supply of a skilled and capable workforce, Germany's innovation ecosystem faces a limited supply of some core skills, which will likely become a greater challenge in the future owing to population ageing. According to the 2018 Mannheim Innovation Survey, 34% of the respondent firms pointed to lack of skilled labour as the most important barrier to innovation, up from 10% in 2006 (ZEW, 2018[37]). The Mannheim Survey also collected data on the number of job vacancies that could not be filled, filled only with delay, or filled with personnel who did not possess the required skills, complemented by information on the type of skills initially required to fill the vacancies. The survey of 1.1 million job openings advertised by 297 000 participating firms in 2017 showed that 18.2% of all vacancies could not be filled by the time of the survey (second and third quarters of 2018), equal to about 200 000 positions. Additionally, 33% (361 000 positions) could be filled only with delay, or only with personnel who did not have the required skills, 48.7% (534 000 positions) of all vacancies were filled as planned.

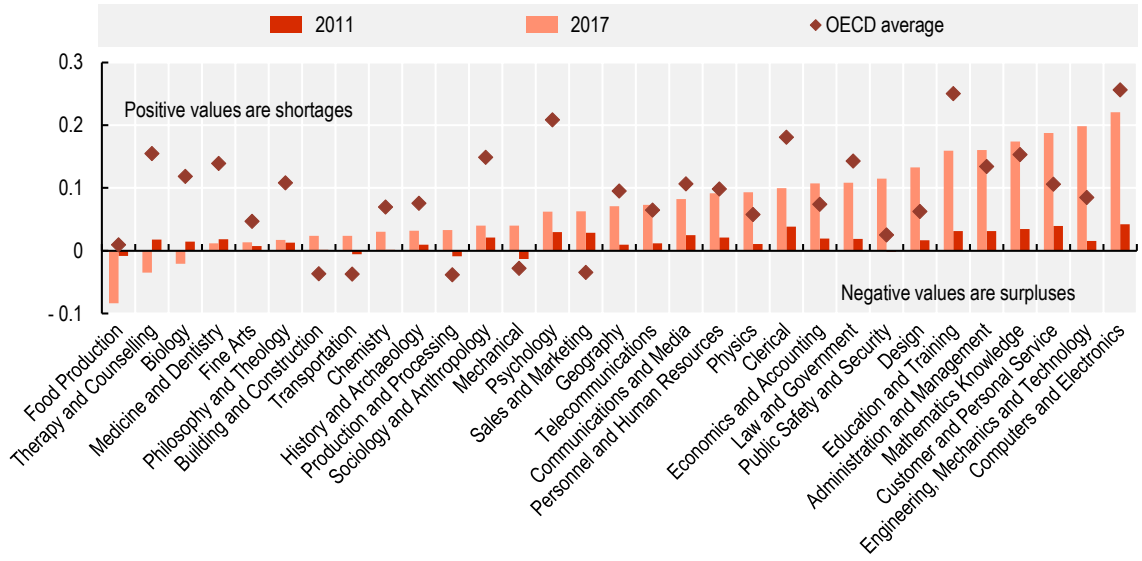
Still according to the Mannheim Survey, 36% of participating firms were seeking new personnel with academic skills in engineering and natural sciences or other academic disciplines, compared to 9% of firms with job openings in computer science, mathematics and statistics. According to some estimates, German firms will need around 700 000 more people with technological skills by 2023 than were available in 2019, particularly skills in complex data analysis and user-centric design (Kirchherr et al., 2020[38]). Moreover, in the future, industries' increasing orientation towards digital services and innovations might require interdisciplinary approaches (Paunov, Planes-Satorra and Moriguchi, 2017[39]).

Seven in ten high-skilled occupations experience skill shortages, one of the highest rates in the OECD (OECD, 2021[40]), particularly in the computer and electronics sectors, engineering and mathematics, and customer and personal services (Figure 6.7). According to the 2019 Skilled Labour Shortage Analysis (*Fachkräfteengpassanalyse*) of the Federal Public Employment Agency, occupational bottlenecks were the largest in medical and care professions, IT, construction and skilled trade (Federal Employment Agency (BA), 2020[41]).

Future labour bottlenecks are likely to be most pronounced in occupations that require a high degree of ICT skills, health care professions, skilled trades, and occupations related to mechatronics and automation technology (BMAS, 2021[42]; Kirchherr et al., 2020[38]; Leifels, 2020[43]). According to a study by the German Economic Institute, in October 2021, there were 276 900 (unfilled) vacancies in STEM roles, which is an increase of 155% on October 2020, but also higher than pre-pandemic figures (October 2019: 263 000). This concerns mainly skilled STEM workers (130 100) and STEM expert roles (103 500) The largest gap was in energy and electronics (81 300), while in 46 400 IT job position could not be filled (Anger, Kohlisch and Plünnecke, 2021[44]). Another report found 96 000 positions for IT specialists to be open in 2021, up by 12% from the previous year, with two thirds of companies reporting shortages (bitkom, 2022[45]).

Figure 6.7. Significant shortages exist in STEM-related knowledge domains

Knowledge domains experiencing shortage or surplus



Note: The *Skills for Jobs* database defines skills as either in shortage or in surplus. These imbalances are measured following a two-step approach. First, an "occupational shortage indicator" is calculated for 33 occupations, based on an analysis of wage growth, employment growth, growth in hours worked, the unemployment rate and the change in under-qualification. For each country, long-run trends are compared to the economy-wide trend. Based on the *O*NET* database, the "occupational shortage indicator" is then used to build indicators of skill shortages and surpluses. Knowledge domains refer to the body of information that makes adequate performance of the job possible (for example, knowledge of mathematics for an economist).
Source: OECD (2020[18]), OECD Economic Surveys: Germany 2020, OECD Publishing, Paris, https://doi.org/10.1787/91973c69-en based on OECD Skills for Jobs database.

An econometric analysis of the data reveals that skill shortages have negative impacts on firms' innovation activities (Horbach and Rammer, 2019[46]). Firms that reported a skill shortage during 2017 (i.e. they could not fill open positions at all, or only with delay, or not with the desired skills) experienced a 11.5% higher probability of abandoning innovation activities (when considering the endogeneity between skill shortage and innovation activities).

6.4.4. Continued education, vocational training and upskilling

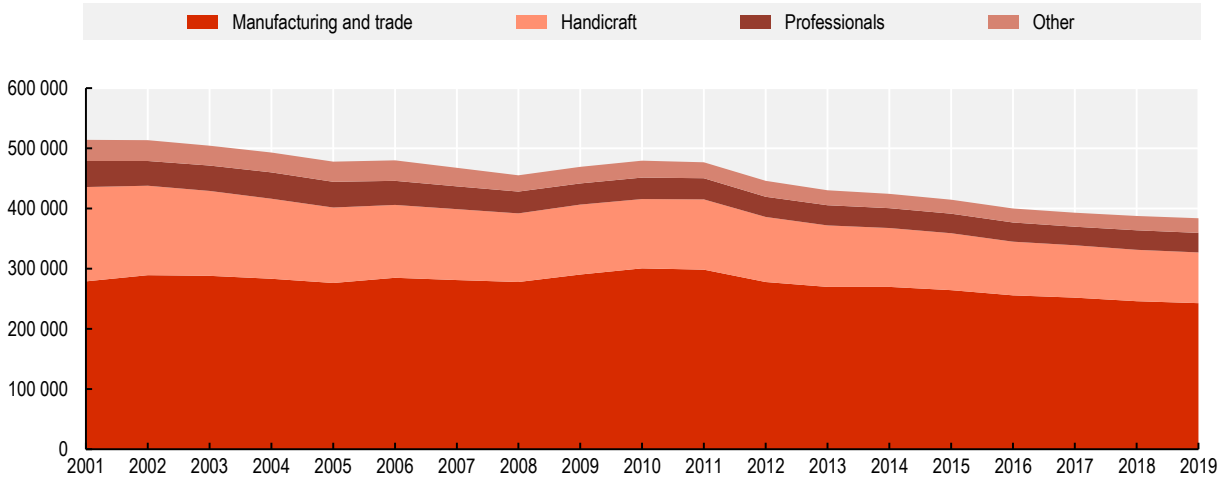
There exist opportunities for continuing education and training (CET) in Germany, but these are used unevenly and not tailored to the more substantive reskilling necessary in light of future transitions. Data from the 2018 German Adult Education Survey suggested that 54% of adults (aged 18-64) in Germany take part in continuing education, a level that is slightly above the EU average of OECD countries (OECD, 2021[40]). However, adults with low skills, low earners and those working for SMEs have particularly low rates of participation (OECD, 2021[47]).

Most CET tends to be rather short and is not aimed at truly transforming workers' skill set and technical competencies, which may be required if existing jobs are displaced and not replaced. Finally, the governance of the CET system is highly fragmented across Germany's states, which may limit a co-ordinated national approach to upskilling and reskilling workers affected by the sustainability and digital transitions. It also generates challenges with regards to accreditation (OECD, 2021[47]).

The growing number of young people embarking on an academic degree in an ageing society, along with the shrinking number of young people in general, implies that the number of graduates from non-tertiary

tracks will decrease. This is clearly the case for the most important education programme in Germany, the dual system of vocational training (Figure 6.8), where the total number of exams passed declined from 451 000 in 2011 to 359 000 in 2019. The decline was particularly strong in handicrafts, manufacturing and trade, and less pronounced in the field of professional services (*freie Berufe*), public services, agriculture and domestic services.

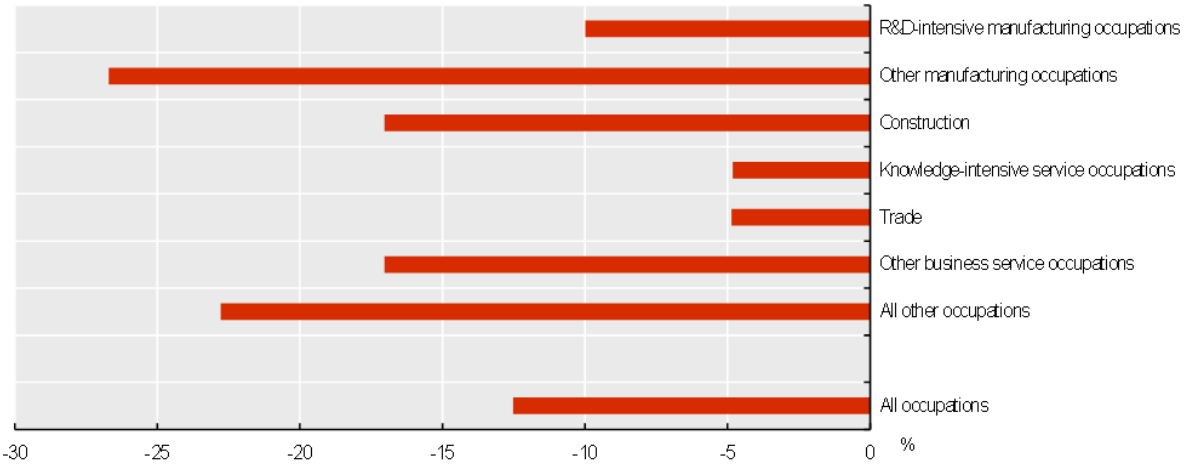
Figure 6.8. Number of passed vocational training exams in Germany, by main area (2001-19)



Source: OECD calculations based on data from Destatis (2022[48])

A closer look at occupations related to different industrial sectors shows a rather moderate decline in passed exams for occupations related to knowledge-intensive services (i.e. ICT; financial and insurance services; and scientific, technical and professional services) and other business services (e.g. transport and storage, and facility management) over 2012-19[1] (Figure 6.9). The number of passed exams declined by 10% in occupations related to R&D-intensive manufacturing and declined more sharply (27%) in other manufacturing occupations.

Figure 6.9. Change in the number of passed vocational training exams in Germany, by related industrial sector (2012-19)



Source: OECD calculations based on data from Destatis (2022[48])

In the context of the socio-economic effects of the digital and climate transitions, it is essential for the adult population to engage in upskilling and reskilling initiatives even later in life to minimise long-term labour displacement and inclusivity challenges. This is particularly important in Germany: according to a 2018 OECD study, around 18% of jobs are at high risk of automation, and an additional 36% of jobs face a significant risk of being displaced (Nedelkoska and Quintini, 2018[49]).

6.4.5. Skilled migration

Germany needs to do more to attract workers from abroad with skill profiles that are in particular demand. According to the 2019 *OECD Indicators of Talent Attractiveness*, Germany is the third most attractive country for international students in the OECD, behind only Switzerland and Norway, and ahead of Finland and the United States. (Chaloff et al., 2019[50]). The student visa system, which allows students to work while studying, combined with low tuition fees, were an advantage for international students. Germany also scored relatively well (sixth) in terms of its attractiveness for migrant entrepreneurs, but in the OECD average in terms of its attractiveness to talented workers.

For companies – particularly smaller firms – facing skill shortages, opting for skilled migration still remains an unusual option. In a 2021 survey of 7 500 companies with more than 10 employees, only 16% said they were recruiting skilled personnel from abroad as a way to prevent skill shortages. Instead, the companies were choosing to offer in-house VET to new employees (47%), make family life and work more compatible (41%), offer further training to existing employees (39%), raise salaries regularly (26%) and offer workplace health management (17%). The 501 responding firms that opted not to recruit foreign skilled workers despite reporting shortages cited language barriers (45%) and uncertainties regarding foreign qualifications (45%) – especially for non-EU workers – as the main reasons for their choice; firms that had actually recruited foreign skilled workers also pointed to language barriers (39%) and foreign qualifications (28%) as major obstacles (39% and 28%, respectively) (Mayer, 2021[51]).

In view of Germany's ageing population, which will affect the future supply of skills, the Federal Government is focusing more on the topic of skilled migration. Issues hindering the success of skilled immigration to Germany include the need to establish formal recognition for foreign qualifications, as well as address the topic of overqualification: only 40% of foreign-born and foreign-educated academics work in a highly skilled occupation, compared to 77% of German academics (OECD, 2020[52]). The skilled-labour migration law (*Fachkräfteeinwanderungsgesetz*), introduced in 2020, aims to ease administrative burdens and contribute to increased inward migration, by increasing and centralising administrative capacities, as well as simplifying requirements for the recognition of qualifications in the ICT sector, where skill shortages are particularly dire (BMWi, 2020[53]). The new government's coalition agreement foresees furthering the issue, including by introducing a point system in which applicants for immigration who have not obtained a job prior to immigrating will be scored according to (among others) their education and language skills (SPD, Bündnis 90/Die Grünen und FDP, 2021[54]; Bayat, 2021[55]). This follows a long-held and widely shared view in Germany of the exemplary character of Canada's immigration system, which also includes point scoring (OECD, 2020[52]).

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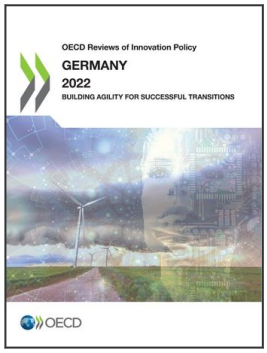
Endnote

[1] The period was chosen due to a break in series between 2011 and 2012 stemming from a change in the classification system of VET occupations.



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