2 Unleashing the benefits of digital transformation

Digital transformation holds important potential for productivity, growth and well-being. The German government has made good progress in addressing some key issues, but much potential remains for unleashing the full benefits of digital transformation and data. Low penetration of high-speed broadband due to few fibre connections and an urban-rural divide in connection speeds, as well as below average mobile broadband data consumption and speeds weaken the foundations for digital transformation. Sluggish adoption of key ICT tools and activities, combined with low investment in knowledge-based capital and digital security concerns, further limits firms' potential to innovate and create value with data. In particular SMEs require support to catch up. Addressing connectivity bottlenecks, incentivising investment and supporting business dynamism during the recovery by reducing administrative burden, facilitating access to financing, and accelerating progress towards digital government can boost technology diffusion and productivity growth. To empower everyone to thrive in digital environments, high demand for numeracy and literacy skills and shortages of ICT specialists, notably among women, need to be addressed. Making the most of digital transformation also requires a national digital transformation strategy and governance that ensures effective policy co-ordination.

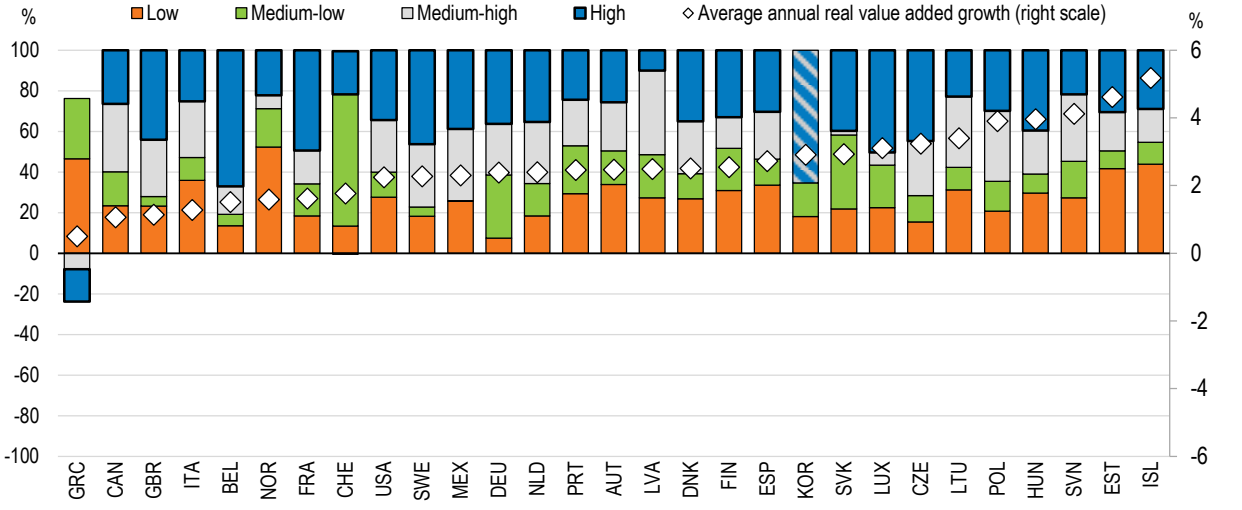
2.1. Boosting productivity and improving policy coherence

Digital transformation holds important potential for productivity, growth and well-being. The German government has made good progress in addressing some key issues, but much potential remains for unleashing the full benefits of digital transformation and data. Digital transformation is underpinned by connectivity, the adoption of ICT tools and activities and effective use of data by firms, governments and individuals, and refers to the economic and societal effects of digitisation[1] and digitalisation[2] (OECD, 2019[1]). Benefitting from digital transformation while addressing challenges across the many areas it affects requires an integrated approach to policy making. Building on core insights from the OECD's Going Digital project, this chapter identifies key priorities for action and recommendations across several policy areas on making the most of digital transformation for Germany. The COVID-19 crisis has illustrated many opportunities of digital transformation for the economy and society, amplifying the importance of several of these recommendations.

In Germany, digital-intensive sectors (high and medium-high) have contributed 62% of growth in value added, compared to 54% on average across OECD countries, between 2015 and 2018 (Figure 2.1). A sector's digital intensity depends on a range of factors, including the adoption of advanced ICT tools, the human capital required for their effective use, purchases of intermediate ICT goods and services, and turnover from online sales, among others (Calvino et al., 2018[2]). Between 2009 and 2018, digital-intensive sectors also contributed 40% of new jobs in Germany, a net creation of 1.6 million jobs.

Figure 2.1. Digital-intensive sectors contributed significantly to recent growth in value added

As a percentage of average annual growth in real value added 2015-18, chain-linked volumes (reference year 2015)



Note: 2015-17 data for Germany, Greece, Latvia, Lithuania, Norway, Poland and Portugal, Switzerland. 2015-16 data for Canada. Digital intensity is defined according to the taxonomy described in: Calvino, F., C. Criscuolo, L. Marcolin and M. Squicciarini (2018), "A taxonomy of digital-intensive sectors", OECD Science, Technology and Industry Working Papers, No. 2018/14, OECD Publishing, Paris, https://doi.org/10.1787/f404736a-en. Factors that define digital intensity of sectors include: ICT tools; human capital needed for their effective use; ICT tangible and intangible (i.e. software) investment; purchases of intermediate ICT goods and services; stock of robots; and turnover from online sales.

Source: Going Digital Toolkit. https://goingdigital.oecd.org/en/indicator/08/.

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Better connectivity, wider diffusion of ICT tools and effective use of data by firms hold important potential for innovation and productivity. Such potential lies, for example, in business processes innovation, automation of routine tasks, more efficient interactions with suppliers and customers, and the use of data in innovation. Labour productivity is high in Germany but is held back by weak capital deepening and slow diffusion of ICT tools and activities to less productive firms (OECD, 2018[3]). In addition to more investment

in ICTs, firms also need to invest in complementary assets: the greatest benefits from digital transformation are often found in firms that also invest in knowledge-based capital and skills (Gal et al., 2019[4]).

Unleashing the full benefits of digital transformation requires coherent policies and co-ordination across all areas affected by digital transformation. This can be achieved through a comprehensive national digital transformation strategy and a governance approach that ensures effective co-ordination. Germany's efforts in this respect are evident. Multiple digital-related strategies and policies exist and the key measures are summarised in the implementation roadmap Digitalisierung Gestalten (Shaping Digitalisation) (Bundesregierung, 2019[5]). This document is co-ordinated by a dedicated unit in the federal Chancellery and serves as a tool to monitor the implementation of existing measures (Box 2.1). The government also allocates significant funding to different aspects of digital transformation (Bundesregierung, 2019[5]), with additional funds being released via the COVID-19 recovery package.

Box 2.1. Towards a national digital transformation strategy

The implementation roadmap Digitalisierung Gestalten presents an important step towards a comprehensive national digital transformation strategy. The document brings together existing and planned digital-related policies across the government in five priority areas: digital skills, infrastructure and facilities, innovation and digital transformation, digital transition of society, and modern state. The document is updated periodically to monitor the implementation of digital-related policies. It will be enhanced with an interactive online dashboard with indicators developed by the federal ministries that are implementing respective policies, designed to measure and provide public information on implementation progress.

Source: (Bundesregierung, 2019[6]; OECD, 2020[7]).

A next step should be to develop a national digital transformation strategy. A comprehensive set of policy areas to consider and key steps for developing a national digital transformation strategy are provided by the OECD's Going Digital Integrated Policy Framework that is designed to help governments improve policy coherence and co-ordination (OECD, 2020[7]). Key steps to develop such a strategy include to: i) identify Germany's overarching vision and priorities for digital transformation; ii) involve all relevant stakeholders into strategy development; iii) integrate and/or co-ordinate (with) all other digital-related strategies and policies and responsible actors; iv) provide clear objectives for each priority area; v) and ensure coherence among the policies designed to achieve these objectives.

A successful strategy requires leadership and governance that ensures effective co-ordination. Currently, most responsibilities for digital-related policies reside in different line ministries. In some cases, ad hoc co-operation across these ministries exist. The federal Chancellery provides light co-ordination in the context of its implementation roadmap, organises digital ministerial cabinet meetings, and has set up a digital council of external experts; it also has a dedicated unit to co-ordinate and develop digital cross-sectional topics such as the forthcoming national Data Strategy. These are useful elements of a governance approach, which however may need to evolve to effectively co-ordinate the development and implementation of a national digital transformation strategy. This may also involve a deeper integration of such a strategy with public funding allocated to digital transformation.

This chapter identifies priority areas and key policy levers to unleash the benefits of digital transformation in Germany. These include: addressing connectivity bottlenecks and increasing quality of service (Section 2.2); strengthening foundations for firms' digital transformation (Section 2.3); overcoming key barriers to firms' successful digital transformation (Section 2.4); supporting business dynamism during the recovery to boost technology diffusion (Section 2.5); and improving skills to thrive in the digital age (Section 2.6). Main findings and recommendations are summarised in a table at the end of the chapter.

2.2. Addressing connectivity bottlenecks and increasing quality of service

Access to fixed and mobile high-quality broadband at competitive prices is a key foundation for people, firms and the government to tap into digital opportunities. The COVID-19 pandemic has shown the essential role of broadband networks as work and education have shifted to homes. For example, 35% of German employees report to have worked partially or completely from home during the enforcement of mobility restrictions in early April of 2020 (SOEP, 2020[8]). As a consequence, demand for broadband communication services has soared, with over 9.1 terabits per second (Tbps) in data transmitted (which equals the simultaneous transmission of up to 2 million high-definition videos), a 120% increase in videoconferencing traffic and a 30% increase in online and cloud gaming at one of the biggest Internet Exchange Points in Frankfurt (DE-CIX, 2020[9]).

Increasingly data-intensive applications are driving demand for more bandwidth, a trend that is set to continue (Cisco, 2018[10]). As for other OECD countries, networks have proven to be resilient during the mobility restrictions of the COVID-19 pandemic (OECD, 2020[11]). However, lacking the fundamental infrastructure for an increasingly data-driven economy and society would restrain Germany's potential to unleash the benefits of digital transformation and to cope with health emergencies, such as pandemics. Proposals in Germany to establish a right to work from home for those workplaces allowing for it, as a response to the COVID-19 pandemic, also depend on the availability of high-quality broadband.

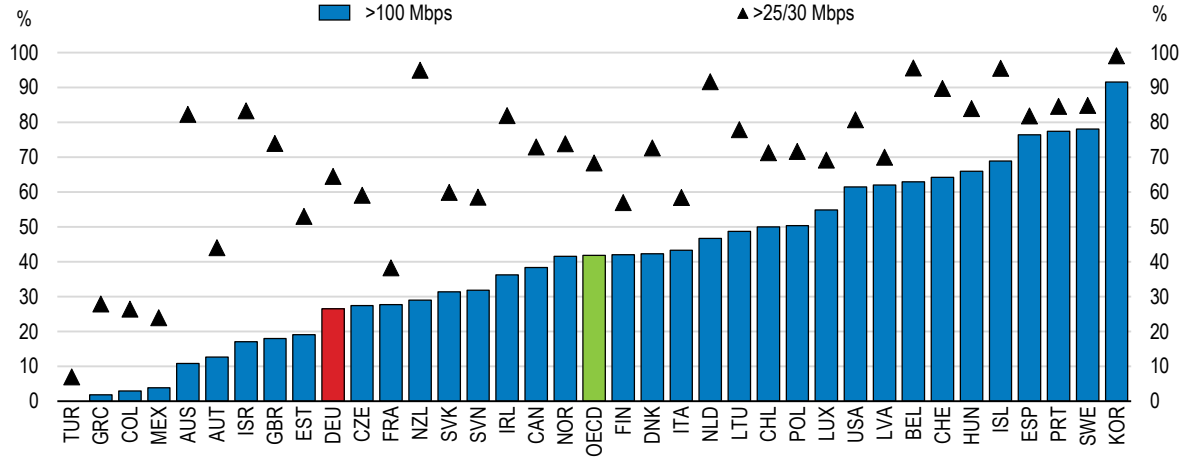
Expand fixed networks and increase their quality

Germany lags behind on broadband subscriptions in higher speed tiers

In 2019, Germany had 42.2 fixed broadband subscriptions per 100 inhabitants, compared to an OECD average of 31.8. However, the share of such subscriptions in the higher speed tiers is low (Figure 2.2). Higher network speeds are important for the use of key ICT tools, such as cloud computing (Section 2.3) and many other data-intensive activities and demanding applications across sectors as for example industry automation, services relying on augmented reality or medical imaging. In addition, high and symmetrical download and upload speeds are necessary to support work from home and use.

Figure 2.2. Germany has a low share of Internet subscriptions in higher speed tiers

Fixed broadband subscriptions with contracted speed faster than 25/30 Mbps and 100 Mbps, December 2019.



Notes: Australia: Data reported for December 2018 and onwards is being collected by a new entity using a different methodology. Figures reported from December 2018 comprise a series break and are incomparable with previous data for any broadband measures Australia reports to the OECD. Speed tier data are only for services purchased over the National Broadband Network (NBN), which comprise the majority of fixed broadband services in operation. There is no public data available for the speed of non-NBN services. Data for Canada, Switzerland and United States are preliminary. New Zealand: Speed tiers are for 2018 instead of 2019.

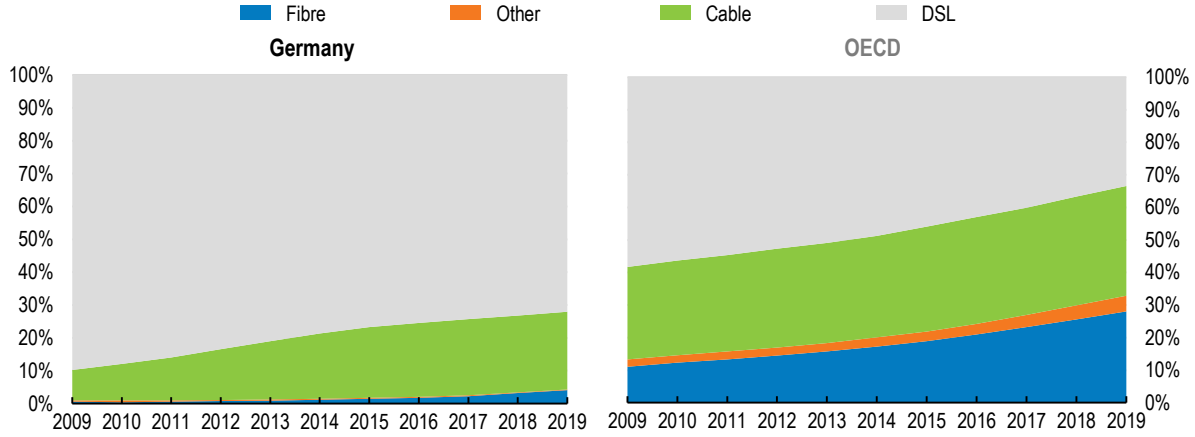
Source: OECD Broadband Portal, https://www.oecd.org/sti/broadband/broadband-statistics.

StatLink https://doi.org/10.1787/888934200964

The low share of faster Internet subscriptions correlates with the infrastructure technology mix in Germany. Digital subscriber line technology (DSL) constitutes the large majority of total fixed broadband subscriptions. The share of fibre-to-the-Home connections is particularly low in Germany at only 4.1%, compared to an OECD average that now reaches 28% (Figure 2.3). DSL connections suffer from an inherent asymmetrical capacity as they use telephone infrastructure that was primarily built for low-speed analogue voice service. Most are characterised by low upload speeds, making them poorly suited to support the increase in telework during the COVID-19 pandemic (OECD, 2020[12]). As data for a large number of fixed broadband operators show, the demand for fibre subscriptions is rising, with a 42% take-up rate for homes connected by these companies (BREKO, 2020[13]). While transitioning from DSL to fibre takes long-term and proper network planning, broadband providers could be encouraged in the medium term to deploy fibre deeper into their networks, gradually phasing out DSL and replacing it with fibre-to-the-home.

Figure 2.3. The share of fibre is low and has increased only slowly in Germany

Technology mix of fixed broadband subscriptions in Germany and the OECD, 2009 – 2019

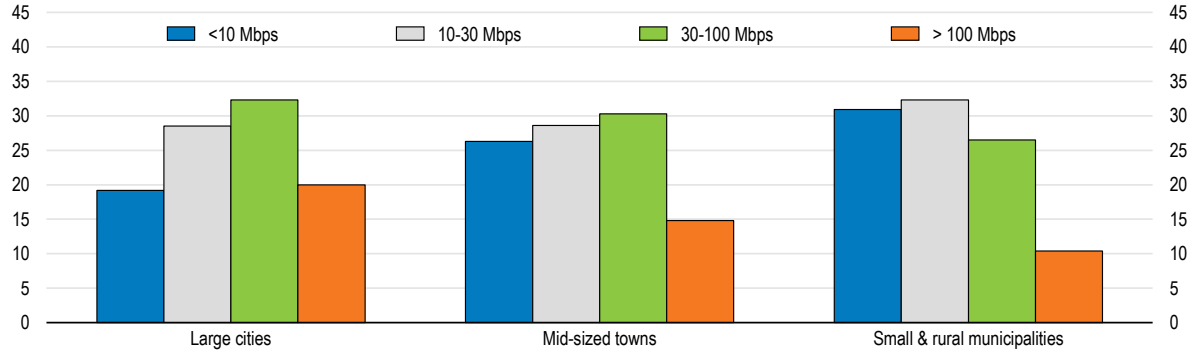


Source: OECD Broadband Portal, https://www.oecd.org/sti/broadband/broadband-statistics.

StatLink https://doi.org/10.1787/888934200983

Figure 2.4. Germany faces an urban-rural divide for Internet subscriptions above 30 Mbps

Broadband subscriptions in firms, 10+ employees, without financial sector, by speed tiers and locations, 2017



Note: Excludes firms without any broadband subscription (around 5% of surveyed firms).
Source: (Alipour, forthcoming[14]).

StatLink https://doi.org/10.1787/888934201002

At the subnational level, larger cities have typically been connected first with higher speed broadband. 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% across rural municipalities (BMVI, 2020[15]). Regional gaps in coverage rates tend to narrow over time. However, Germany's urban-rural divide translates into

regional disparities with respect to higher speed broadband subscription rates among firms (Figure 2.4 above). Small and rural municipalities lagged behind large cities by a factor of two regarding local firms' subscription rates to broadband of at least 100 Mbps in 2017 (Alipour, forthcoming[14]).

Only a small amount of public funds for broadband deployment has been disbursed

The German government has recognised this gap and has set an ambitious goal for high-speed connectivity in its coalition agreement: nationwide gigabit Internet coverage by 2025 (CDU, CSU and SPD, 2018[16]). To achieve this goal, the federal government has put in place a number of public broadband subsidies. Between 2016 and 2030, around EUR 11 billion has been or will be made available by the Federal Government's state aid programme for broadband deployment. This includes 70% of special assets ("Sondervermögen Digitale Infrastruktur"), financed mostly by the EUR 6.6 billion in revenue generated by the 2019 spectrum auction (to be paid in instalments until 2030), which are channelled into Gigabit network deployment. Additional funds of approximately EUR 11 billion are provided by the *Länder*.

However, only a small amount of the disposable funds of the Federal Government's state aid programme has been paid out so far. As of September 2020, only EUR 750 million had been paid out. One of the reasons for delays in the disbursement of funds is the German two-stage system of granting subsidies and drawing on funds. In this system, a preliminary grant approval decision has to be issued by the competent authority and the disbursement of funds is triggered only when the construction process reaches certain pre-agreed milestones, which often take a long time to be achieved. Germany has taken measures to improve this process, such as the establishment of a focus team for project acceleration and a federal project management agency. However, the two-stage system should be further simplified. This includes reducing administrative procedures to ease the participation of smaller providers. In addition, funds are only paid out very late in the process, which might act as an additional barrier given that network deployment is capital intensive. The government could review this practice to ensure that the programme is taken up more widely.

Streamline administrative processes and rights of ways to spur fixed infrastructure deployment

Another reason for insufficient infrastructure deployment may be the long administrative processes, including for rights of way. The German Law for the Facilitation of the Expansion of Digital High-Speed Networks ("Gesetz zur Erleichterung des Ausbaus digitaler Hochgeschwindigkeitsnetze", DigiNetz Act) implemented the European Union's Cost Reduction Directive 2014/61/EU and is aimed at speeding up network deployment and reducing respective costs. However, processing times for applications submitted to municipalities ("Wegebaulastträger") still take three to four months, which adds to the total length of rights of way approvals, delaying network expansion.

In addition, approval procedures are not streamlined and often require approval from several different public authorities. While Germany plans to take measures to accelerate approval procedures in the context of the upcoming amendment of the Telecommunication Act, additional steps should be taken to shorten administrative approval times and streamline rights of way processes, respecting the responsibilities of relevant entities at different levels of government. In Spain for example, the Ministry of Energy, Tourism and Digital Agenda examines whether a municipality's management instruments comply with the Spanish Telecommunication Law through periodic reports.

Construction bottlenecks as described in the Key Policy Insights also play a key role as private companies as well as municipalities have struggled to commission construction works in a timely manner. At times, this even hinders applications for public subsidies as deployment timelines cannot be met. Another reason for slow fibre deployment may be the reluctance to use alternative deployment methods such as microtrenching, i.e. laying fibre less deep. While the DigiNetz Act allows for microtrenching, this option has

been little used. Measures that ease the use of alternative deployment methods are foreseen in the upcoming amendment of the Telecommunication Act.

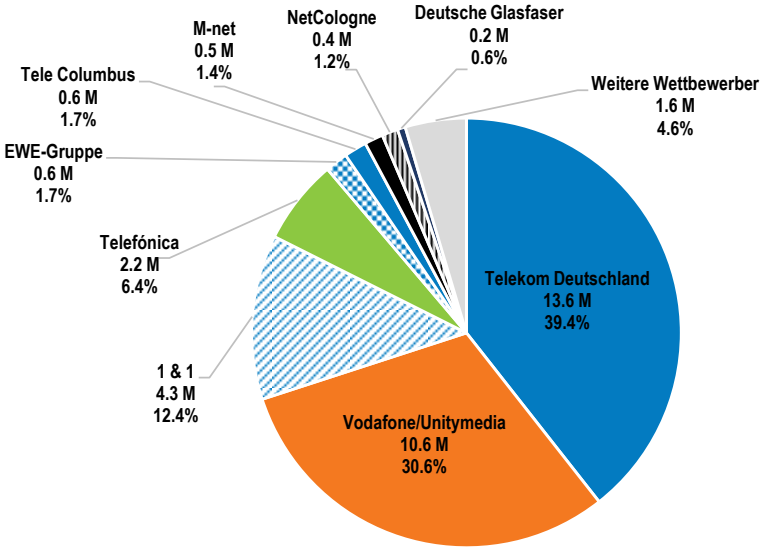
More competition in the fixed broadband market could boost high-quality broadband

Another factor in low penetration of high-speed subscriptions may be that costs lower uptake rates: fixed broadband connections are relatively expensive in Germany compared to peer countries. In June 2020, German consumers paid USD PPP 43 for a connection of 100 Mbps and above (360 GB per month), compared to USD PPP 36 in France, USD PPP 38 in Italy, USD PPP 40 in Sweden (Strategy Analytics, 2020[17]).

Comparatively higher prices often reflect the state of competition in a country. With Vodafone's acquisition of Liberty Global's (Unitymedia) business in Germany in 2019, the competitive landscape is currently undergoing significant changes. On the one hand, the merger might lead to an increase in network speeds as Vodafone might upgrade existing cable lines, which, in turn, might incentivise more fibre deployment. Moreover, the merger remedy of granting Telefonica access to Vodafone's cable network might enable Telefonica to compete with bundled services containing high-speed Internet access. On the other hand, Deutsche Telekom and Vodafone now own more than 70% of fixed broadband connections, while Deutsche Telekom alone owns almost 40% of connections (Figure 2.5). It will be important for the relevant authorities to continue to monitor competitive dynamics in the market for fixed broadband services in Germany. In addition, competition in connectivity of multi-dwelling buildings can be fostered.

Figure 2.5. Germany has a concentrated fixed broadband market

Fixed broadband market shares by number of customers, July 2019



Source: (VATM, 2019[18]).

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Current legislation in Germany allows for housing cooperatives and property management companies to sign bilateral contracts with network operators, which require all tenants to pay a monthly fee for the connection. Historically, these operators have mainly been cable companies. Consequently, this makes existing cable connections relatively more attractive, as accessing a different service would require a tenant to pay for both connections. This may represent an entry barrier for communication operators other than cable network operators (Monopolkommission, 2011[19]). While the legislation has been extended to allow a similar approach for non-cable TV services, it still favours existing connections. Eliminating this legislation would lower switching costs for consumers to other providers and increase competition between different network operators.

To further promote competition while at the same time reducing deployment costs, Germany could promote in-building infrastructure (and cost) sharing for fibre wiring in multi-dwelling buildings. For example, current legislation in France imposes symmetrical obligations for the party deploying in-building fibre wiring and requires operators that have deployed a fibre optic network in a building to comply with reasonable requests for access from other operators.[3] An agreement determines the technical and financial conditions of access between the concerned parties and any refusal of access has to be justified (Gouvernement de la République française, 2019[20]).

To further foster competition, Germany should also facilitate passive infrastructure sharing, i.e. the sharing of network elements such as ducts and cabinets, and increase the transparency of existing passive infrastructure such as ducts. While the German infrastructure information system "Infrastrukturatlas" aims at providing this transparency, the tool could benefit from being fully digitalised, from being easily accessible and publicly available, as well as from additional features such as geo-referencing and displaying prices of usable assets directly to the user. The upcoming amendment of the Telecommunication Act, which foresees the creation of a central information system, presents an opportunity to revise the current infrastructure information system and address its shortcomings. Mexico has set up such an information system to foster infrastructure sharing and deployment (Box 2.2). Increased access to ducts has had positive fibre-to-the-home deployment effects in countries such as France, Spain and Portugal. In addition, communication operators could be encouraged to jointly invest with other infrastructure providers, such as local electricity providers. Measures such as dig-once policies or the joint use of ducts can increase efficiency and lower the costs of infrastructure deployment.

Box 2.2. Increasing the transparency for infrastructure deployment in Mexico

In Mexico, the Secretariat of Communications and Transportation (SCT) issued an interagency agreement that allows for close to 110 000 state-owned structures to be used and shared, by concessionaires (licensees), permission-holders and infrastructure developers, as passive infrastructure for telecommunication networks under non-discriminatory, equal-access and non-exclusive conditions. Information pertaining to the relevant properties, including geo-referenced location, as well as physical, economic, technical, safety and operational conditions and the market value are published on an on-line platform called ARES operated and managed by Institute for National Assets (Instituto de Administración y Avalúos de Bienes Nacionales, INDAABIN). Interested parties can use the platform as a search engine and indicate their interest in a particular building and INDAABIN will serve as a one-stop portal for all the requests. Apart from the 110 000 federal buildings, other interested public institutions, for instance at the municipal level can become a member of the portal and present their properties that fulfil the necessary technical conditions.

Increase mobile network coverage and quality

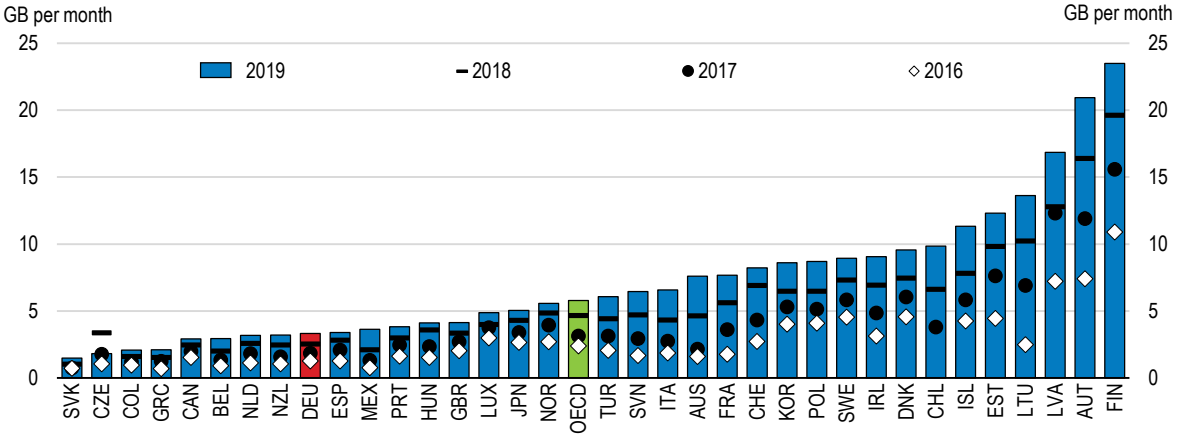
Germany has fallen behind on mobile broadband subscriptions, speeds and data usage

Although mobile broadband services have been a major driver of increasing connectivity in Germany over recent years, subscriptions are well below the OECD average. While there are 87 mobile broadband subscriptions per 100 inhabitants in Germany, the OECD average is 114.5. Germany has also fallen behind the OECD average on mobile data usage (Figure 2.6). Low data consumption may be linked to comparatively higher prices among peers for larger mobile data packages as well as differences in prices between third generation (3G) and fourth generation (4G) mobile data packages. In May 2020, German consumers paid around USD PPP 34 for a 10 GB data plan (including 900 calls), while consumers paid USD PPP 22 in Spain, USD PPP 24 in France, USD PPP 27 in Italy, and USD PPP 29 in Sweden (Strategy Analytics, 2020[17]).

Germany is also falling behind on mobile network performance. The average download speed on Long Term Evolution (LTE) networks in Germany is below the OECD average according to two different providers of speed tests, which provide different perspectives on and measurement of the mobile Internet (Figure 2.7). Moreover, download speeds on LTE networks are not even available in all parts of Germany, as white spots with no or only second generation (2G) connections are still common in Germany (zafaco GmbH, 2020[21]).

Figure 2.6. German mobile broadband subscribers consume less data than the OECD average

Mobile data usage per mobile broadband subscription, 2019

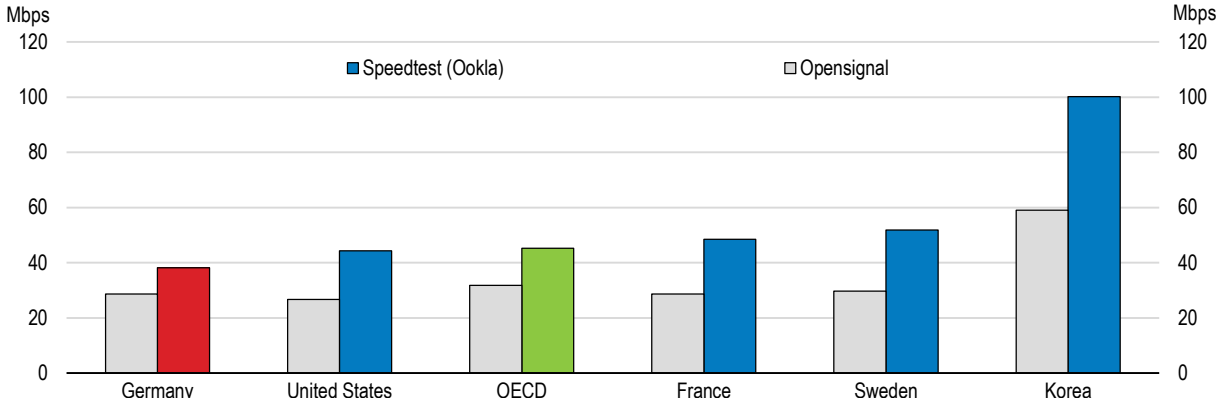


Note: The multiplier 1024 is used to convert TB into GB; the total amount of GB is divided by the yearly average number of Mobile broadband subscriptions. Australia: Data reported for December 2018 and onwards is being collected by a new entity using a different methodology. Figures reported from December 2018 comprise a series break and are incomparable with previous data for any broadband measures Australia reports to the OECD. Data for Canada and Switzerland are preliminary. OECD average includes estimates.
Source: OECD Broadband Portal, https://www.oecd.org/sti/broadband/broadband-statistics.

StatLink https://doi.org/10.1787/888934201040

Figure 2.7. Germany has fallen behind peer countries on mobile download connection speeds

Average download speed on LTE networks for selected countries and the OECD, 2020



Note: Speedtest (Ookla) data are for May 2020, Opensignal data are for the average download connection speed on Long-Term Evolution networks, collected between 1 January and 30 March 2020.
Source: Speedtest (Ookla), www.speedtest.net/global-index, Opensignal, https://www.opensignal.com/reports/2020/05/global-state-of-the-mobile-network.

StatLink https://doi.org/10.1787/888934201059

Ensure fast implementation of the national mobile strategy and streamline rights of ways for mobile infrastructure

Germany has also set itself ambitious targets for mobile access. Contracts signed between the federal Ministry of Transport and Digital Infrastructure (BMVI) and mobile network operators at the 2018 mobile telecommunication summit aim for an LTE coverage of 99% of all households throughout Germany by the end of 2020, and a 99% LTE coverage of all households in each federal state by 2021 (BMVI, 2019[22]). The German mobile strategy ("Mobilfunkstrategie"), published at the end of 2019, aims at closing gaps in the LTE network and making Germany a leading country in fifth generation cellular networks (5G) (BMVI, 2019[23]). Following the COVID-19 pandemic, the German Government is planning to direct an additional EUR 5 billion towards 5G infrastructure development (BMF, 2020[24]).

While these initiatives are welcome, a timely and effective implementation of measures to improve access to public properties, to speed up approval procedures, and to facilitate access to information on infrastructure deployment will be crucial to achieve the strategy's objectives. Measures such as the amendment of the Federal Highway Law that eliminates minimum distance rules for cell towers close to highways are welcome. Nevertheless, the overall procedure to construct a cell tower currently takes two to two and a half years as most of the time is spent on the determination and acquisition of locations to build the towers (OECD, 2019[25]). As mentioned above, Germany could improve its information system "Infrastrukturatlas" to facilitate the identification of available public assets.

Successful entry of a fourth operator will depend on a national roaming agreement

The 2019 auction of spectrum in the 2 Gigahertz (GHz) and 3.6 GHz bands paved the way for 5G deployment in the country. While Deutsche Telekom received most of the spectrum, the auction allowed for the entrance of a new player with 1&1 Drillisch, which has the potential to significantly spur competition in the German mobile market. The auction was linked to coverage obligations, which could considerably improve coverage and increase network speeds. Obligations included each operator's commitment to a minimum data rate of 100 Mbps available by the end of 2022 for 98% of households in each state, all federal highways, all main roads and along the major railway routes. Also, each carrier must install 1 000 5G base stations and 500 other base stations in defined areas by the end of 2022. At the end of 2024, 5G coverage should be extended to seaports, main waterways and all other road and rail routes (RCR, 2019[26]).

The entrance of a fourth operator can significantly spur innovation and competition in the German mobile market, as observed in other OECD countries (such as Chile and France) when a fourth operator entered the market. Currently, the market is characterised by less innovation in terms of contracts offered compared to other European markets such as France and Finland, where for example more "roam like at home" contracts, more unlimited data offers or more flexible contract durations can be found. In addition, none of the three mobile network operators provides a mobile post-paid contract with a minimum contract period below 24 months.

For the fourth operator to substantially increase competition in the mobile market, it will be important for it to close a domestic roaming agreement with one of the three existing mobile network operators, as has been the case for the entrance of Iliad Free to the French market. In addition, the fourth operator needs to be considered when current spectrum licences expire, especially the band below 1 GHz. Existing spectrum licenses should not be extended automatically as this would undermine the improvements in competition stemming from the entry of a fourth player. In addition, it is important to ease and promote passive infrastructure sharing due to positive effective cost reductions especially in rural and remote areas. If Germany also envisages active infrastructure sharing, consideration should be given to safeguarding an adequate level of mobile communications infrastructure competition.

Operators need to upgrade and extend fibre backhaul for 5G network deployment

An important prerequisite for a wide 5G deployment is to deploy fibre deeper into mobile backbone networks and to lay fibre to mobile cells in order to offload mobile traffic into fixed networks. Not all mobile cells and towers are currently connected to fibre networks. It is expected that all German network operators need to significantly deploy more fibre in their networks to achieve the goals in the mobile strategy and to enable 5G.

Since November 2019, the German regulator has made spectrum available for corporate licences for local 5G industry campus networks, enabling major industry players to run their own private networks in the frequency range of 3.7 to 3.8 GHz. Industry players interested in these frequencies indicated that they may want to use these frequencies for automation processes as well as for agriculture. While this may help German companies to increase efficiency in production, it is important to award all frequencies to users as soon as possible. This will allow for an assessment of the amount of spectrum that may be unused and the development of a plan for its efficient use. As of September 2020, 74 of the reserved frequencies have been awarded out of 78 applications (Bundesnetzagentur, 2020[27]).

2.3. Strengthening foundations for firms' digital transformation

High-speed and affordable broadband is an essential but not a sufficient foundation for firms' successful digital transformation. It can be considered a general-purpose technology (Bresnahan and Trajtenberg, 1995[28]) that underpins productivity and economic growth (Czernich et al., 2011[29]; Rohman and Bohlin, 2012[30]). High-speed broadband has become crucial for many firms, in particular in knowledge-intensive sectors, as illustrated by its fundamental role for increased teleworking during the COVID-19 crisis (OECD, 2020[12]). However, reaping the gains from broadband requires firms of all sizes, across sectors and territories to adopt a wider set of ICT tools and activities, which together can boost competitiveness, spur innovation and increase productivity (Draca, Sadun and Van Reenen, 2009[31]; Gal et al., 2019[32]).

Table 2.1. Firms with higher speed broadband are more likely to adopt other ICT tools and activities
Estimated percentage point change in the likelihood of adopting ICT tools and activities for German firms by speed tiers of broadband subscription

	ERP	CRM	e-purchase	e-sales	Social media	Cloud computing	BDA
100+ Mbps subscription	3.32***	3.07***	1.12	4.321***	9.75***	6.85***	3.07**
30-100 Mbps subscription	1.60*	2.06**	2.57***	2.87***	6.61***	6.96***	-1.20
Observations/Firms	24685/22316	24593/22241	24857/22467	30126/26511	26330/22724	9488/8546	5821/5821
Survey years	2012-2015, 2017	2012, 2014, 2015, 2017	2012-2015, 2017	2012-2017	2013-2017	2014, 2016	2016

Note: Firms with 10 or more employees, excluding financial sector. ERP stands for enterprise resource planning, CRM for customer relationship management, BDA for big data analysis. This table reports OLS regression results based on representative repeated cross-section survey data of German firms for the period 2012-2017. Dependent variables equal 100 if a given ICT tool or activity is adopted and 0 otherwise. Coefficients reflect the percentage point change in the likelihood of a firm adopting a given ICT tool or activity associated with broadband speed tiers of 100+ Mbps and 30-100 Mbps, respectively compared to a baseline speed of <10 Mbps. In addition to a broad set of control variables, regressions (except big data) control for year, municipality and industry (4 digit) fixed effects. Big data uses fixed effects at the county level instead of the municipality level. Standard errors are clustered at the municipality level (not reported); ***, ** and * denote significance at the 1%, 5% and 10% level, respectively. Table A1 in the Annex provides additional detail.
Source: (Alipour, forthcoming[14]).

Firms' adoption of high-speed broadband tends to correlate with the adoption of other ICT tools and activities. Table 2.1 (above) reports estimates on the complementarity between firms' broadband

subscriptions by speed tiers (30-100 Mbps or 100+ Mbps) and their adoption of other ICT tools and activities in Germany. These tools and activities enable firms to perform in increasingly knowledge-intensive economies, optimise processes and integrate into digital markets, and collect, store, exchange and analyse big data. The complementarity between the speed of Internet subscriptions and other ICTs are strongest for key tools that enable firms to create value with data such as cloud computing and social media as well as with tools that enable digital market integration and process optimisation such as e-sales, customer relationship management (CRM) and enterprise resource planning (ERP).

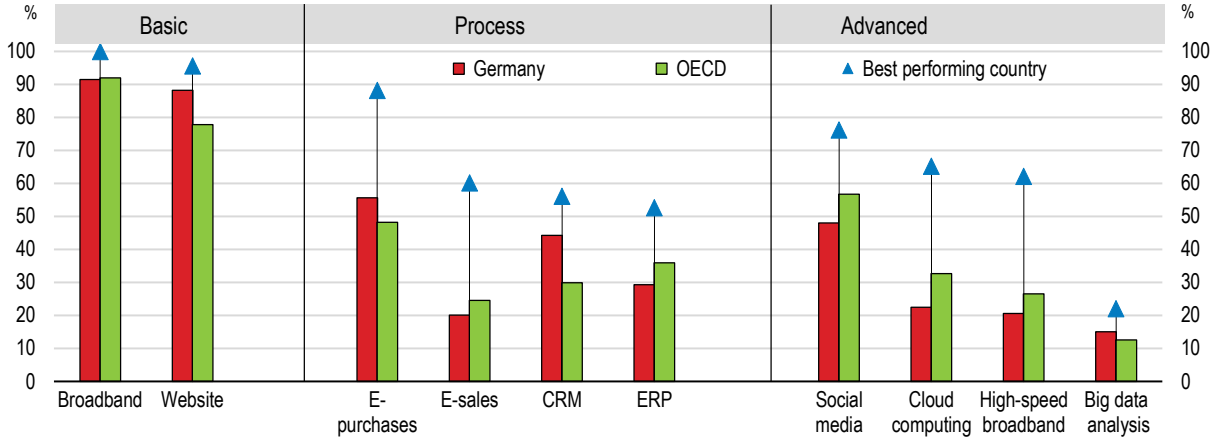
Foster firms' adoption of ICT tools and activities needed to create value with data

Basic ICT tools such as broadband and websites, which enable firms to digitise information and establish a presence online, are widely diffused in Germany. ICT tools and activities that enable firms to digitalise and optimise processes, such as CRM are fairly well diffused too, as are 3D printing and robots, notable industrial robots in large firms (OECD, 2019[33]; Eurostat, 2018[34]). However, Germany is not among the best performing countries in the OECD for most process-related ICT tools and activities and remains even below the OECD average for ERP and e-sales (Figure 2.8), including for e-commerce intensity (e-commerce in total turnover) (OECD, 2019[35]).

For more comprehensive digital transformation and data-driven innovation, firms will need to adopt newer and more advanced ICT tools and activities notably those that enable them to collect, store, exchange and process (big) data. Firms in Germany significantly lag behind in the adoption of most of these tools and activities, including high-speed broadband (100+ Mbps), cloud computing and social media. Shares of firms with a high-speed broadband subscription or that purchase cloud computing are less than half of those in the best performing countries (Figure 2.8). On big data analysis (BDA), German firms have caught up between 2016 and 2018. Some more general catch-up is evident in above average growth rates in firms' adoption of other advanced ICT tools (except for high-speed broadband) over recent years. An important sector in which Germany has fallen behind in digital transformation is health (Box 2.3).

Figure 2.8. German firms lag in the adoption of advanced ICT tools and activities

% of firms, 2019 or latest year available



Note: Firms with 10 or more employees, excluding financial sector. ERP stands for enterprise resource planning, CRM for customer relationship management; high-speed broadband are subscriptions with 100+ Mbps.

Source: OECD ICT Access and Usage by Businesses database, http://oe.cd/bus.

StatLink https://doi.org/10.1787/888934201078

Firms notably lag in the adoption of cloud computing. Cloud computing can be used for advanced process optimisation and for many data-intensive applications in firms. The share of firms in Germany that purchase cloud computing is over 40 percentage points (pp) below the best performing country (Finland) and 8pp

below OECD average. In particular medium-sized firms lag far behind (-14pp) the OECD average. This is striking, given that smaller and younger firms tend to be key beneficiaries from cloud computing in other countries, leveraging the cost-efficiency and flexibility of scaling up and/or down digital operations as compared to legacy information technology (IT) infrastructure (Bloom and Pierri, 2018[36]). Firms in Germany lag behind for all types of cloud computing and across all sectors, with the largest gaps (all firms) occurring in manufacturing (-11pp to average) and transportation and storage (-10pp to average).

Box 2.3. Digital transformation of Germany's health care system

Digital transformation of the health care system holds important potential for Germany. For example, electronic health records (EHR), telemedicine, electronic prescriptions and automated reimbursements could bring important efficiency and monetary gains, estimated at EUR 34 billion (about 12% of health spending) in 2018. Around 70% of these gains would come from digital transformation in health care delivery, i.e. notably physicians and hospitals, compared to 30% from effects in sickness funds (McKinsey, 2018[37]).

Germany's health care system showed strength in successfully managing the COVID-19 pandemic. This should not divert attention from the fact that Germany has fallen behind many other countries in the digital transformation of health care. Germany lags important digital health fundamentals, including digital services, ranking 16th out of 17 countries analysed in the Bertelsmann Digital-Health-Index, which covers 13 EU member states, the UK and 3 other OECD countries. Contrary to Germany, in Estonia and Denmark citizens can already consult diagnostic results and vaccination data online, and telemedicine practices are commonplace in Canada and Israel (Bertelsmann Stiftung, 2018[38]).

Telemedicine turned out particularly beneficial in the context of the COVID-19 pandemic by allowing continuity of certain health care in times of social distancing while reducing infectious exposure (CDC, 2020[39]). More generally, telemedicine can improve safety and cost-effectiveness, and can in some cases lead to better health outcomes than conventional face-to-face care (Oliveira Hashiguchi, 2020[40]). Despite evident benefits, telemedicine still represents a small fraction of all health care activity and spending in Germany. In 2017, less than 10% of Germans used telemedicine, compared with 18% in the EU and almost 50% in Estonia and Finland. The share of general practitioners who use electronic networks to exchange medical data with other providers is low too, and so is the use of electronic prescriptions (European Commission, 2019[41]).

Evolutions in the legal framework over recent years have significantly improved the conditions for digital transformation of Germany's health care system. For example: the 2015 E-Health Act introduced a basic statutory electronic patient record and a roadmap for building a telematic infrastructure; the 2019 Drug Safety and Supply Act expanded the possibilities of tele-medicine through new rules for electronic prescriptions (BMG, 2019[42]); the Appointment-service and Care Act mandates sickness funds to introduce an electronic patient record by 2021 at the latest (BMG, 2019[43]); and the 2019 Digital Healthcare Act brings additional improvements, e.g. with regards to online video consultations and access to a secure healthcare data (BMG, 2019[44]).

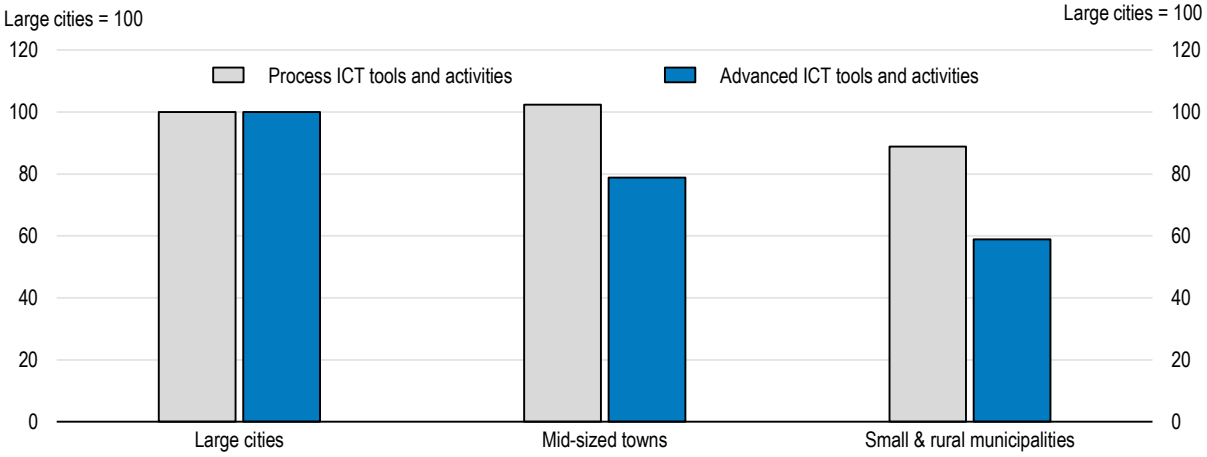
Source: (Bertelsmann Stiftung, 2018[38]; BMG, 2019[42]; BMG, 2019[43]; BMG, 2019[44]; CDC, 2020[39]; European Commission, 2019[41]; McKinsey, 2018[37]; Oliveira Hashiguchi, 2020[40]).

Firms' backlog on newer and more advanced ICT tools and activities is most visible outside of large cities. As a federal and quite decentralised country, Germany has many important firms outside large cities, including "Mittelstand" firms, many of which are small and medium-sized (SMEs, 10-249 employees) or mid-range (250-3000 employees) enterprises. The use of newer and more advanced ICT tools and activities in small and rural municipalities is almost a third lower than in large cities (Figure 2.9). In contrast,

firms in smaller towns and rural municipalities are almost as likely as in large cities to use process-related ICT tools and activities. This is in line with the finding that the share of firms with lower Internet speed subscriptions (below 30 Mbps) does not decrease in smaller towns and rural areas (Section 2.2, Figure 2.4). It might also indicate that process-related ICT tools and activities require less bandwidth than newer and more advanced ones that enable firms to create value with data.

Figure 2.9. Firms in small and remote places lag furthest on advanced ICT tools and activities

User rates (index) across settlement types in Germany, by types of ICT tools and activities, 2017 or latest available



Note: The index of user rates is set to 100 for large cities. Process ICT tools and activities include e-purchases, e-sales, customer relationship management and enterprise resource planning; data for these are for 2017. Advanced ICT tools and activities include cloud computing, big data analysis and social media; data for these are for 2016.
Source: (Alipour, forthcoming[14]).

StatLink https://doi.org/10.1787/888934201097

Creating value with data, for example through data-driven innovation, often requires big data analysis (OECD, 2015[45]; Niebel, Rasel and Viete, 2019[46]). Germany has caught up fast over recent years with the OECD average on the share of firms performing big data analysis, from 6% in 2016 (-5pp to average) to 15% in 2018 (+2pp to average), and also reduced the distance to the best performing country from 13pp to 7pp over the same period. However, a closer look at firms' performance of big data analysis by sector and data source provides a mixed picture. While key sectors such as manufacturing and transport are above average, the gaps to the best performing country remain important across all sectors (Figure 2.10, Panel A).

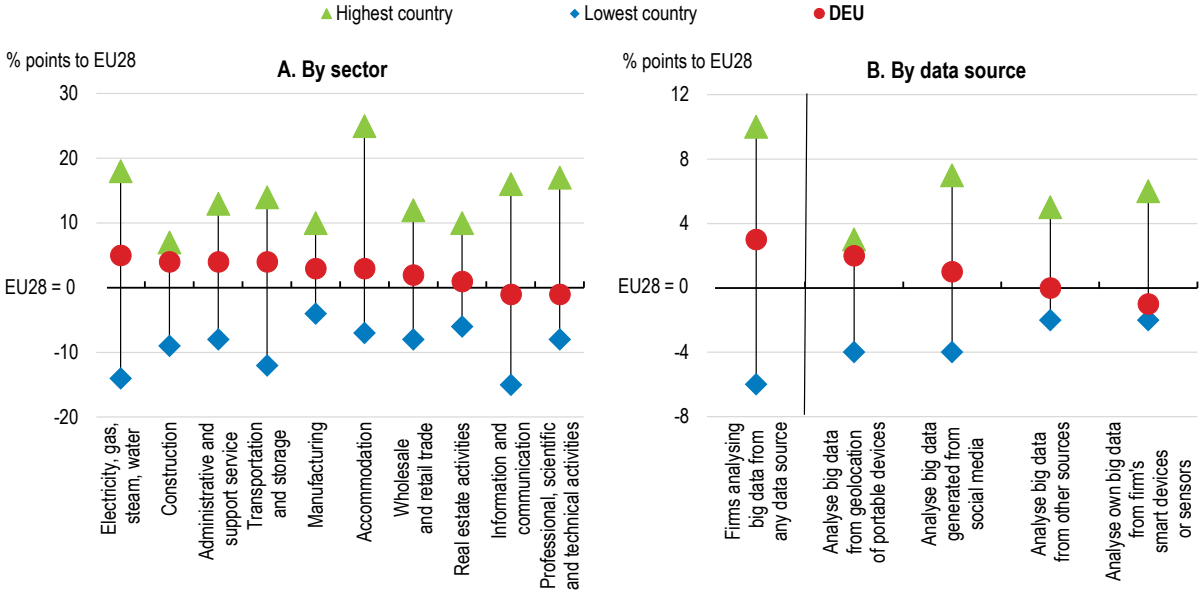
Much of firms' potential to create value with data in Germany and Europe is considered to reside in the use of firm-related and machine generated data in the context of industry 4.0, which is of strategic importance for factory automation in German industries (BMWi, 2019[47]). Generally, firms that invest for the first time in digital technologies tend to focus more strongly on the potential of data, notably data from their own operations and machines (Bitkom, 2018[48]). Strikingly, only 3% of firms in Germany use data from their own sensors or devices to perform big data analysis, which is below the European Union (EU) average of 4% (Figure 2.10, Panel B) and far less than in leading countries, such as the Netherlands (10%), Finland (8%) and Belgium (7%). Data on the geolocation of portable devices and from social media, which are more likely customer-related data, are the most widely used data sources for firms' big data analysis in Germany.

The government has recognised the urgent need to boost firms' collection, sharing and effective use of data, notably with project GAIA-X that establishes key building blocks for a federated European data infrastructure to strengthen Europe's competitiveness in global digital and data-driven markets (Box 2.4). The government is also developing a Data Strategy, which has been announced as covering four main areas: 1) improving data sharing and securing access to data, 2) promoting responsible data usage and

increasing the potential for innovation, 3) improving data competencies and establishing a data culture, 4) Making the state lead by example (Bundesregierung, 2019[49]). It is crucial that this strategy provides an effective data governance framework, including for a data-driven public sector, to enhance access to and sharing of data, and includes ambitious objectives and measures to help firms boost their collection and use of data, for example measures concerning open data, data portability, and contractual agreements (OECD, 2019[50]). Australia and Finland are considered to be advanced among OECD countries that have or are developing a national or sector-specific data strategy.

Figure 2.10. Data from firms' sensors and devices remains underused for big data analysis

% firms performing big data analysis, differences in percentage points to EU28 average, 2018 or 2016



Note: Firms with 10 or more employees, excluding financial sector.
Source: (Eurostat, 2018[34]).

StatLink https://doi.org/10.1787/888934201116

The more data firms collect and use, the more relevant AI becomes to create value with data. Fast growing investments in AI over recent years reflect high expectations of its potential. Globally, the United States attracts the largest share of equity investments in AI start-ups, although China is rising fast, while Europe attracts only a small share. Within the European share, Germany accounts for only 14% of investment, after the UK with 55% (OECD, 2019[51]). Diffusion of AI in firms, such as for data analytics, natural language processing, image recognition, and automation (OECD, 2019[33]) is still poorly measured and probably at an early stage. The most advanced users of AI tend to be large firms that are already sophisticated users of ICT tools and activities, notably in the ICT, automotive and financial services sectors. However, important potential looms in many other sectors too, e.g. in retail, media and entertainment, health care, and education (MGI, 2017[52]; OECD, 2020[53]). AI's crosscutting applicability has become evident also for tackling the COVID-19 pandemic, for example in predicting the evolution of the virus or accelerating medical research on drugs and treatments (OECD, 2020[54]).

Box 2.4. GAIA-X: towards a federated data infrastructure for Europe

GAIA-X is an ambitious project to create a federated and trustworthy data infrastructure for Europe in a strengthened European Digital Single Market. The project aims to benefit data subjects and data controllers by fostering data sharing and innovation with the mission to strengthen digital sovereignty for business, science, government and society and to unleash digital and data-driven innovation. Initiated by the Federal Ministry for Economic Affairs and Energy (BMWi) and the French Ministry for Economy and Finance, GAIA-X involves industries from both countries, in particular cloud services providers and customers (BMWi and BMBF, 2019[55]; BMWi, 2020[56]). Representatives from several European countries are currently involved and other European partners from business, science and politics are invited to join.

GAIA-X is conceived as a European digital ecosystem that can be distinguished in three ways. 1) A data ecosystem that fosters ontologies for interoperability and application programming interfaces (APIs) within and across sector specific data spaces according to the EU data strategy. This should facilitate the emergence of smart services, artificial intelligence (AI), and big data market places and applications. 2) An infrastructure ecosystem that enables services based on common standards. This involves network and interconnection providers, cloud solution providers, high performance computing as well as sector specific clouds and edge systems. 3) Federation services to operate the GAIA-X ecosystem, following the principles of security by design and privacy by design in order to ensure highest security requirements and privacy protection, while supporting the free flow of data (BMWi, 2020[57]; BMWi, 2020[58]).

GAIA-X also relates to the European Data Space initiative that is part of the European Data Strategy (EC, 2018[59]) (EC, 2020[60]), which aims to create a genuine single market for data. For example, one initiative that could provide impetus for the implementation of the European Data Strategy in the mobility sector is the current expansion and optimisation of Germany's National Access Point for traffic and mobility data as part of the German Mobility Data Space, promoted in the framework of the German Presidency of the EU Council. This Data Space could contribute to the development a common European Mobility Data Space that connects the national access points of the participating member states (EC, 2020[61]).

Source: (BMWi and BMBF, 2019[55]; BMWi, 2020[56]; EC, 2018[59]; EC, 2020[60]; BMWi, 2020[57]; BMWi, 2020[58]; EC, 2020[61]).

Germany's AI Strategy recognises the important role of data and AI and bundles a range of (mostly existing) initiatives including on data infrastructure, data governance, and industrial data (BMWi, 2019[47]). An update of the strategy is currently underway. Investments of EUR 3 billion support the strategy's implementation. So far, EUR 1 billion was allocated in two tranches via the federal budgets for 2019 and 2020 to be spent until 2022 and 2023 respectively. An additional EUR 2 billion will be allocated via the COVID-19 recovery package. Important parts of Germany's AI funding is targeting scientific AI-related research, as put into practice in the Cyber Valley in Tübingen, Europe's largest AI research consortium with scientific and business partners. This should ultimately strengthen Germany's position among the top countries for AI-related publications and patents (OECD, 2019[33]; Baruffaldi, 2020[62]). Additional measures should be considered to boost the adoption of AI in firms alongside the range of policy instruments that can foster the adoption of ICT tools and activities more generally (Box 2.5; Sections 2.3. and 2.4).

Box 2.5. Fostering the adoption of ICT tools and activities by firms

Different types of policy instruments can be used to promote the adoption of ICT tools and activities by firms. Most common is direct financial support, followed by indirect financial support and other measures such as regulatory guidance or sandboxes.

Financial support includes direct financial support measures for firms' adoption of ICT tools, such as for cloud services (Korea), big data (Portugal), digital consultancy services and digital skills (Denmark, Slovenia). Indirect financial support includes tax credits or other relief for ICT investment (Brazil, Japan) and subsidies to credit institutions to enable lending at preferential rates to firms in priority sectors that invest in digital products (Russian Federation).

Non-financial measures often raise awareness of the opportunities and risks of ICT tools and activities, for example via tailored advice and counselling services (Australia, Lithuania, Sweden), including on regulations relevant to new business models (Turkey) or by sharing the experience of "digital champions" or offering mentoring schemes (Portugal, Slovenia). Other measures include guiding principles and assessments to ensure that regulation is fit for digital transformation. For example, Denmark introduced a mandatory assessment of regulation to ensure it facilitates new business models, is technology-neutral, and ensures user-friendly digitalisation.

Regulatory sandboxes are another non-financial measure that allows firms to test new ICT tools and activities in a real-world environment while providing the opportunity for advancing ICT-related regulation through regulatory learning. With its Regulatory Sandbox Strategy, Germany aims to systematically establish regulatory sandboxes as frameworks for testing innovation and regulation across technologies and policy areas (BMWi, 2020[63]).

Source: (OECD, 2020[64]); (OECD, 2020[65]); (BMWi, 2020[63]).

Firms' effective use of ICT tools and data underpins innovation across sectors (OECD, 2019[66]). While Germany has long been considered a world leader in technology, engineering and innovation (EC, 2012[67]) the innovative edge of many German firms cannot be taken for granted in the digital age. Germany still has a high share of innovative firms, as measured by the Eurostat Community Innovation Survey. However, this share decreased by over 16pp between 2008 and 2016, while it increased by almost 15pp in the Netherlands and by 10pp or more in Great Britain, Finland, and Belgium; the latter two now have a higher share of innovative firms than Germany (Duc and Ralle, 2019[68]). Germany's initiatives to boost firms' digital innovation potential, including in the context of industry 4.0 (BMWi, 2019[69]), such as via the High-tech Strategy and the Regulatory Sandbox Strategy (BMBF, 2018[70]; BMWi, 2020[63]), are crucial in this context. However, they need to be complemented with measures that overcome key barriers to firms' successful digital transformation (Section 2.4), including to boost investment in knowledge-based capital. This is paramount for firms of all seizes across all sectors and particularly urgent for firms operating at the digital frontier, such as those in the automotive industry.

Strengthen the automotive industry's capacity for data-driven innovation

Firms in the automotive industry need to innovate in business models to capture the increasing share of digital value in their core products and to remain competitive with new entrants, including players from outside the automotive industry. The automotive industry is Germany's largest industrial sector, accounting for around 20% of total German manufacturing industry revenues and 4.7% of gross domestic product (GTAI, 2018[71]). The COVID-19 crisis reduced demand for German cars, and with plant closures production over the first nine months of 2020 was down by one third compared with the same period in 2019 (VDA, 2020[72]). This adds to existing challenges resulting from global trade and the transition to

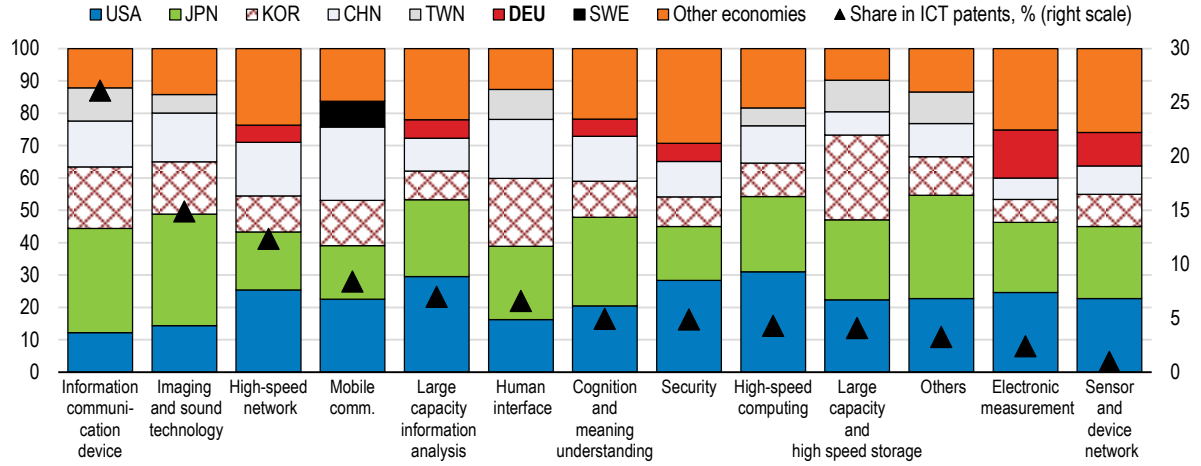
alternative power trains, electrification in particular. Against this background, automotive firms are facing digital transformation at several fronts: in production and innovation, in their core products, and in evolving (urban) mobility patterns that are shaping the role, use of, and demand for cars (ITF, 2019[73]).

The German automotive industry is a leader in industry 4.0, championing the digitalisation of business processes and supply chains and the automation of production systems (WEF, 2016[74]). Key benefits from industry 4.0 are improvements in cost, quality and delivery, including through closer co-operation with suppliers, transparent inventory management and just-in-time/sequence logistics, shorter material lead times, and improved in-plant material flows (Kern and Wolff, 2019[75]). While the industry in Germany has remained strongly focussed on the digitalisation of production and logistics (VDA, 2018[76]), its core products, cars in particular, have started transforming through fast-paced digital and data-driven innovation. A growing share of cars' value is moving from the mechanical, physical good to the car as a digital platform. This transformation has increased the importance of connected systems and autonomous driving for the industry (SAP, 2018[77]).

Compared to other industries in Germany, the automotive industry performs well on specific patents for the industry's digital transformation, but Germany is not an international leader in ICT-patents and related R&D spending. German automotive firms account for 43% of International Patent Classification patents in "Electric Digital Data Processing" (IW, 2018[78]). However, on a range of ICT-patents Germany lags behind the top players, featuring among the top five in less than half of the ICT-related patent categories shown in Figure 2.11. In contrast, the United States, Japan, Korea and China dominate across all of these categories. The same countries are also home to the top corporate research and development (R&D) investors contributing most to develop AI-related technologies (EC and OECD, 2019[79]). Overall, Germany's share of ICT-related patents in the total number of IP5 patents (patents from the world's five largest IP offices) is below the OECD and EU averages and R&D expenditures in ICT equipment and information services are low (OECD, 2017[80]).

Figure 2.11. Germany lags behind top economies in ICT-related patenting

Share of the top five economies' shares of patents in ICT-related technologies, 2014-17



Note: Data refer to IP5 families, by filing date, according to the applicants' residence using fractional counts. Patents in ICT are identified using the list of IPC codes in Inaba and Squicciarini (2017).

Source: OECD, STI Micro-data Lab: Intellectual Property Database, http://oe.cd/ipstats, September 2020.

StatLink https://doi.org/10.1787/888934201135

A central development in the evolution of cars is autonomous driving technology, which requires ICT hardware and software that are not among the traditional German industrial strengths. Cars capable of level 4 automation (the highest level is 5) are on the road in test mode and sales of vehicles with this degree of automation could rise significantly by 2030 (McKinsey, 2016[81]). While German manufacturers

hold 55% of autonomous driving related patents worldwide, co-operations of suppliers with several manufacturers may lead to fast diffusion of autonomous driving innovation, which may undermine long-term advantages (Bardt, 2017[82]). Software is also often not patentable in Europe and can be supplied globally by few players. In addition, leading firms of key automated driving hardware, such as microprocessors, are not based in Germany (ifo, 2019[83]). These aspects could undermine the strength of Germany's automotive sector over time, if value creation in the industry increasingly relies on innovation in and production of ICTs.

On the one hand, autonomous driving could weaken German premium cars' core value propositions such as driving dynamics or precision steering, with implications for the margins that companies gain from selling premium cars that can be re-invested in R&D (ifo, 2019[83]). On the other hand, automation is an opportunity for German manufacturers to innovate in new functions and services to remain competitive. Autonomous driving may further underpin evolutions in mobility that affect the role of cars in the value chain. High and full autonomy may allow passengers to dedicate more time in mobility to other activities than driving, for example work and entertainment. This would shift even greater shares of value from cars as physical goods into services offered and data collected in mobility. This may benefit firms controlling more segments of the value chain, such as Tesla, which is involved in battery production, autonomous driving technology and software, direct retailing and insurance (Chen and Perez, 2018[84]).

The creation, delivery and capture of value that resides in digital components and services requires business models and competencies that are not common in the automotive industry, for example competencies related to networks, software and data. Today, these tend to be concentrated among established digital technology companies, many of which have entered the autonomous vehicle market already (CB, 2019[85]). Some of them have made important in-roads, for example, in autonomous driving (e.g. Waymo) and cars' digital operating (e.g. Android Automotive OS) and infotainment systems (e.g. Apple CarPlay). These entrants can leverage interoperability and synergies with other digital platforms they operate, including cloud computing. On key services, such as autonomous driving, German automotive firms may increasingly have to partner with foreign companies that have the talent, expertise, and networks needed to excel in data-driven value creation.

The government has advanced several initiatives over recent years in support of the automotive industry's digital transformation. Building on the 2015 Strategy for Automated and Connected Driving, the 2018 action plan Digitalisation and Artificial Intelligence in Mobility bundles several measures related to data usage, vehicle automation, connectivity, real world test beds, ethical rules, legal and regulatory reviews, and international standardisation (BMVI, 2015[86]; BMVI, 2018[87]). A large testbed was established on the A9 highway with a focus on automated and connected driving and related infrastructure implications. Urban testbeds in several major German cities are serving to trial interactions between vehicles, infrastructure and other road users and to gather experience for industry and research in real traffic and driving situations of varying complexity. These testbeds should also allow citizens to experience the potential of new technologies "hands-on" and provide insights for further policy decisions (BMVI, 2017[88]). Germany also participates in two Important Projects of Common European Interest, one on microelectronics (EUR 1 billion) and one on the battery value chain (EUR 1.25 billion), and runs a programme on ICTs in electro mobility (BMVI, 2019[89]; BMWi, 2018[90]; European Commission, 2019[91]). In the context of the COVID-19 crisis, the government provided demand stimuli by temporarily lowering VAT and increasing incentives for purchasing electric cars.

In addition to addressing the industry's need for skills (Section 2.5) more attention should be paid to standard-setting, in particular with regards to connected and automated driving, which is shaped by multiple technologies and industries with complex interoperability implications (VDA, 2018[76]; NPM, 2020[92]). Germany has not been a front-runner so far on ICT-related standard setting for connected and automated driving, where international standardisation bodies and consortia play an important role. The establishment of Working Group 6 of the National Platform on the future of Mobility and Germany's engagement at the European level as well as in the Working Party on Automated/Autonomous and

Connected Vehicles within the World Forum for Harmonization of Vehicle Regulations (WP29) of the United Nations Economic Commission for Europe are good steps. However, sustained efforts are needed to catch up with countries such as Japan and China that are considered to have taken a lead in using standardisation as a strategic instrument to shape the state of the art of technical solutions and regulatory guidelines (VDA, 2019[93]). Germany's automotive industry would benefit from the pursuit of a more strategic and co-ordinated approach to standard-setting related to autonomous driving technologies across standardisation bodies, consortia and industry domains (OECD, 2017[94]).

Digital transformation also underpins changes in mobility patterns that are likely to affect the role, use of, and demand for private cars, in particular in cities. Key trends that are likely to shape urban mobility include shared mobility services and autonomous driving, both of which rely heavily on ICTs. In the long-run, intra-urban travel may shift more to public transport and shared mobility (ITF, 2019[73]). While global demand for private cars is still on the rise, the International Transport Forum estimates that between 2015 and 2030, growth in urban transport demand (passenger-kilometres) in the OECD will be strongest in shared mobility (15%, including all modes), while demand for private cars may slightly decrease. In a scenario in which all private car use is replaced by the massive uptake of shared mobility in conjunction with existing public transport systems, vehicle-kilometres and CO_2 emissions could be reduced by 30-60%, compared to current mobility patterns (ITF, 2019[73]).

An important step underway to improve Germany's legal framework for evolving urban mobility is the current review of the Personenbeförderungsgesetz (Passenger Transport Act) that may improve the conditions for ride- pooling (BMVI, 2019[95]). Other initiatives include the government's mFund, which supports investment in data-driven innovation, research projects, SMEs and start-ups in mobility (EUR 200 million 2016-2020 and EUR 250 million starting 2021), and the German Association of the Automotive Industry's Urban Mobility Platform that involves major cities, automotive firms and suppliers and aims at launching pilot projects (VDA, 2018[76]). Looking ahead, strategic considerations should take into account the interrelated and increasingly converging trends of automated driving, shared mobility and alternative powertrains.

2.4. Overcoming key barriers to firms' successful digital transformation

Germany should address three key barriers to digital transformation: first, low investments in ICTs and knowledge-based capital that are crucial for the effective use of data and to drive innovation; second, specific hurdles faced by SMEs; third, concerns about digital security that discourage many firms from adopting key ICT tools, such as cloud computing.

Boost investment in knowledge-based capital

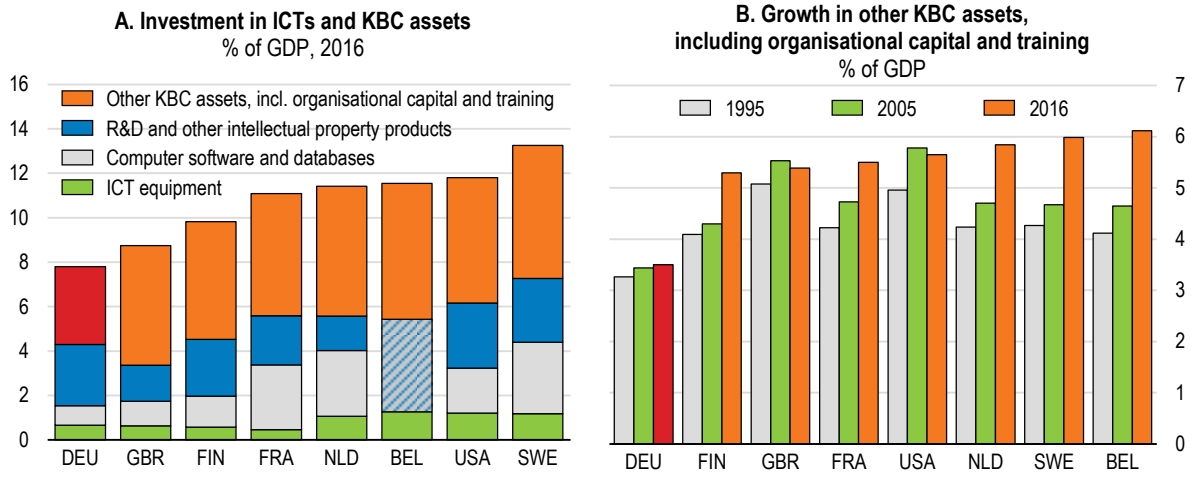
Unleashing the potential of digital transformation for innovation and productivity requires firms to invest not only in ICT equipment but also in knowledge-based capital, including R&D, intellectual property, software, data, organisational capital, design and training (OECD, 2013[96]). Investment in knowledge-based capital has significant effects on productivity in Germany, notably when combined with investments in tangible assets (DIW, 2017[97]). However, low levels and sluggish growth of investment in knowledge-based capital undermine the innovation potential of German firms (Bertelsmann, 2019[98]; BDI, 2020[99]) and the contribution of knowledge-based capital to productivity growth (OECD, 2018[3]; Demmou, 2019[100]). This may also relate to low growth of knowledge-intensive services in Germany, compared with other countries such as the United Kingdom and the United States (SVR, 2019[101]).

In Germany, investment in knowledge-based capital is low and tends to be concentrated in only a few sectors and firms. While investment in R&D is above and in ICT equipment is close to the respective OECD average, investments in software and databases are less than two thirds of the OECD average (OECD,

2019[33]). Investments in other knowledge-based assets, including organisational capital and training have remained low over the past three decades, compared to best performing countries (Figure 2.12). In addition, investment in R&D, software, licences, patents are concentrated in a small number of larger firms in a few sectors, in particular in the manufacturing sector for R&D (car manufacturing accounts for 30%) and the ICT sector for software (the ICT sector accounts for 40%). Investments in organisational capital and training are spread out more broadly across sectors (DIW, 2017[97]).

While Germany's gross domestic expenditure on R&D is at the higher end among OECD countries and has increased over the past decade, the share of business R&D in value added in industry (2.17%) is below OECD average (2.54%) and decreased between 2005 and 2015. However, the intensity of business R&D adjusted for industrial structure is above OECD average, which can be explained by the German economy's relative specialisation in R&D intensive industries. Strikingly, the SME share in business R&D is below 10%, compared to over 60% in the ten countries with the highest share (OECD, 2017[80]).

Figure 2.12. Investment in ICTs and knowledge-based capital is low



Note: KBC stands for knowledge-based capital. No breakdowns of intellectual property products available for Belgium. Other KBC assets are estimated based on INTAN-Invest data and cover all industries except real estate, public administration, education, health and households.
Source: OECD calculations based on OECD National Accounts database and INTAN-Invest data, http://www.intaninvest.net/.

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A key policy instrument to address R&D market failures are expenditure-based R&D tax incentives, which account for 55% of total government support for business R&D in the OECD area in 2017, up from 30% in 2000 (OECD, 2020[102]). Germany introduced R&D tax incentives in early 2020, subsidising 25% of maximum EUR 2 million R&D expenditures per year, limited to EUR 15 million in total (direct and tax) support per firm (BMF, 2019[103]). As part of the COVID-19 recovery package, this cap has been increased to EUR 4 million per firm until the end of 2025 (BMF, 2020[104]). While this measure is expected to benefit R&D in SMEs, the initial cap is likely to limit the effects for larger "Mittelstand" firms, so called mid-range companies, which are key players for innovation with important potential for R&D (ZEW, 2018[105]; ZEW, 2019[106]). Based on closely monitoring the instrument's uptake, further refinements should consider increasing the cap and account for the role of direct R&D support (Appelt et al., 2020[107]). Monitoring and potential refinements of the instrument should also consider interactions with related instruments such as the Central Innovation Programme for SMEs (Zentrales Innovationsprogramm Mittelstand) (BMWi, 2019[108]; ifo, 2019[109]) and the potentially complementary depreciation allowance for "digital goods" that is currently in planning.

Knowledge-based assets themselves can act as a barrier to accessing asset-based financing, in particular for SMEs. Lenders often face important challenges to recognise SMEs' knowledge-based assets as collateral, and may struggle to understand their role for firms' success, how to value these assets, and how

to realise value in case of a default (Brassel and Broschmans, 2019[110]). Where bank financing plays a dominant role, as in Germany, this can work against investment in knowledge-based assets (OECD, 2019[111]). This might partly explain or reinforce the technology bias in digital-related investments of SMEs' in Germany, 83% of which invest in technology, compared to only 64% that invest in related skills (European Commission, 2018[112]). Germany may consider other countries' approaches to address this issue. For example, the French public investment bank Bpifrance supports investments in knowledge-based capital through uncollateralized loans and bank loan guarantees, and the French Ministry of the Economy and Finance launched a website to help businesses and investors develop knowledge-based capital intensive business strategies (DGE, 2018[113]). The UK's Intellectual Property Office subsidises IP audits for SMEs, which helps strengthen SMEs' IP protection strategies and creates awareness of knowledge-based asset value (OECD, 2019[114]).

The need to reduce information and financing barriers to firms' investments in knowledge-based capital and ICTs should also be reflected when reviewing key digital related strategies and policies, such as the Digitale Strategie 2025 (Digital Strategy 2025) and the Mittelstand-Digital (SME Digital) strategy, which currently lack attention to this issue (BMWi, 2016[115]; BMWi, 2019[116]). Beyond WIPANO, a programme for knowledge and technology transfer via patents and standards that promotes the patenting and exploitation of inventions and funds research projects on standardisation, and the above-mentioned incentives to invest in R&D, policies should aim to boost firms' investments in software, databases, organisational capital and training, which remain particularly low compared to other countries (Figure 2.12 above). Existing programmes that provide investment incentives for some of these forms of knowledge-based capital, such as the ERP Digitalisierungs und Innovationskredit (KfW, 2020[117]), could be scaled up, including with more funding.

Step up support to accelerate the digital transformation of SMEs

SMEs are at the heart of the German economy, champions in some international niche markets, and key partners of larger multinationals as upstream suppliers. Germany's SMEs play a key role in automotive industry supply chains, and account for the bulk of the German international trade surplus (VDA, 2018[76]; OECD, 2019[118]). While in the context of the COVID-19 crisis SMEs suffered in many sectors, IT and telecommunication were among the few sectors that experienced increasing demand, for example to support telework (Meffert, Mohr and Richter, 2020[119]). To remain competitive in an increasingly digital and data-driven economy, including with less mobile staff and customers during containment, SMEs need to invest more in advanced ICTs, knowledge-based capital and the skills they need to succeed in digital transformation (Section 2.6).

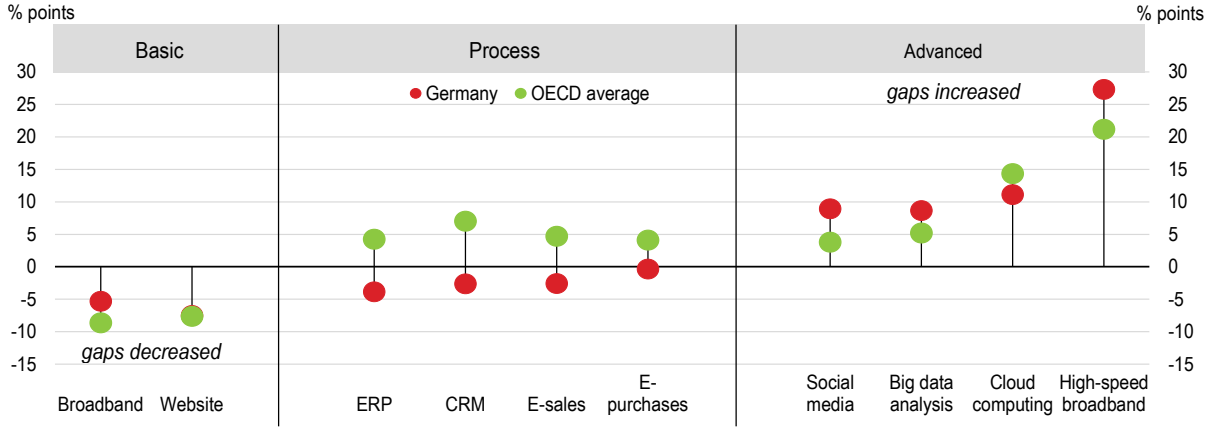
Over recent years, digital transformation trends of German SMEs have shown a positive dynamic, but gaps with larger firms remain. Between 2016 and 2018, 40% of SMEs completed digitalisation projects successfully, which corresponds to some 1.5 million SMEs, up from 26% between 2014 and 2016 (KfW, 2020[120]). However, large firms remain frontrunners in the adoption of newer and more advanced ICT tools and activities that enable firms to create value with data. Across OECD countries, the gap between large and small firms is closing for the adoption of basic ICT tools, and in Germany this is also the case for process-related ICT tools and activities (Figure 2.13). Large firms, however, still drive the adoption of newer and more advanced ICT tools and activities, in most cases, even more so in Germany than across OECD countries. This may also reflect Germany's general backlog in the adoption of such tools and activities (Section 2.2, Figure 2.4 above), in particular of high-speed broadband. Policies supporting their adoption should thus notably target smaller firms.

SMEs often face barriers to access external finance and many invest only little in their digital transformation. Key reasons include uncertainty about success, difficulties for lenders to assess digital transformation projects and a low share of investments that could account as collateral. In part as a result, SMEs tend to finance digital transformation projects mainly from their cash-flow (Saam, Viete and Schiel,

2016[121]). Currently, SMEs finance such projects by 87% with internal funds, while bank loans only account for 7%, a proportion that does not necessarily reflect firms' first choice. Indeed, firms conducting loan negotiations on digital transformation projects are more likely to report difficulties in accessing credit than enterprises negotiating loans for capital expenditure (KfW, 2020[122]). Over the past three years, average digitalisation expenditure stagnated at EUR 17 000 per firm. The EUR 19 billion SMEs invested in digitalisation in 2018 remains low compared to the EUR 34 billion spent on traditional innovation and the EUR 220 billion spent on material assets (KfW, 2020[120]).

Figure 2.13. Small firms are not yet catching up in the adoption of advanced ICT tools and activities

Percentage point change in the gap between small and large firms for the adoption of ICT tools and activities, 2010 to 2019 or latest available



Note: Firms with 10 or more employees, excluding financial sector. For Germany, data refer to 2013-2014 for using social media, purchasing cloud computing services and 2016 for having performing big data analysis. For OECD average, data refer to 2011-15 for using social media, 2009-14 for purchasing cloud computing services and 2016 for having performing big data analysis.
Source: OECD ICT Access and Usage by Businesses database, http://oe.cd/bus.

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Policies in support of SMEs' digital transformation include several well-targeted measures. The government's 2019 Mittelstand-Digital strategy raises awareness and provides guidance on digital transformation for SMEs (BMWi, 2019[123]), including through Mittelstand 4.0 Kompetenzzentren, which provide local contact points offering specific digital expertise to SMEs (BMWi, 2017[124]). The Go Digital programme subsidises authorised digital transformation consultants for SMEs (BMWi, 2018[125]), and the recently launched Digital Jetzt (Digital Now) programme subsidises investments in ICTs, including software and related training in firms with 3-499 employees (BMWi, 2019[126]). Several additional programmes exist at sub-national level. The largest programme, Digital Now, provides around EUR 50 million annually over four years (BMWi, 2020[127]). While in sum this is substantial, more may be needed to significantly accelerate the digital transformation of the over 2 million eligible firms.

Policies to foster the adoption of ICTs in SMEs should be carefully designed so as not to discourage firms' expenditures on digital services that are crucial for their digital transformation. Recent OECD analysis found that specific ICT capital incentive programmes in the UK and in Germany were associated with lower adoption of digital services that firms do not account for as capital but as operating expenditure, notably cloud computing (Andres et al., 2020[128]). It is thus important to design policies not only to incentivise investment in physical ICT capital but also to encourage firms to increase expenditures on digital services. For example, the depreciation allowance for "digital goods", which was suggested in the coalition agreement (CDU, CSU and SPD, 2018[16]) and is currently in planning, may benefit from considering SMEs' expenditures on digital services such as cloud computing, in addition to investments in digital goods such as computer hardware and software.

SMEs also often struggle finding the skills and building the organisational capital they need for using ICTs effectively. Through its Initiative New Quality of Work, the Federal Ministry of Labour and Social Affairs created several measures to support SMEs in this regard. This includes Innovation Spaces to experiment digital work arrangements and processes (BMAS, 2020[129]), Hubs for Tomorrow to test innovative in-house training approaches, with a focus on eastern German states (BMAS, 2020[130]), a Centre for Digital Work that supports these hubs with research findings on labour market evolutions induced by digital and demographic change, and Corporate value: Human, a programme that provides guidance and support, including subsidies for consulting, to help SMEs create or adapt their human resource strategy (BMAS and ESF, 2020[131]). Further development of these initiatives should be considered in the larger context of education and training policies (Section 2.6).

Promote digital security risk management more strategically

In the context of the COVID-19 pandemic, many firms have increased their digital activities, for example teleworking. More digital operations can create additional exposure and increase vulnerability to digital security threats, which have markedly increased since the COVID-19 outbreak (OECD, 2020[132]). A single digital security incident can disrupt operations, lead to loss of innovation assets, or destroy reputation, with potentially existential implications for the firm. In 2019, 11% of firms in Germany experienced digital security incidents with implications for the availability of digital services, the destruction or corruption of data, or the disclosure of confidential data. This is slightly below the EU average of 13% (Eurostat, 2019[133]) and may partly reflect lower exposure of firms in Germany to digital threats due to their sluggish adoption of advanced ICT tools and activities that are essential to collect, store, exchange and analyse data (Figure 2.8 above). Overall, cybercrime and related losses in Germany are estimated to exceed EUR 50 billion per year (BMWi, 2019[116]).

Digital security concerns are an important barrier to the adoption of key ICT tools and activities in Germany. The use of cloud computing, including for software and database hosting, is particularly affected by security concerns (Hentschel, Leyh and Petznick, 2018[134]). Such concerns are high in Germany both compared with other countries, and compared with other obstacles to cloud computing such as interoperability or skills (ZEW, 2015[135]). These concerns may help explain the low adoption of cloud computing in firms to date (Figure 2.8 above).

Many German firms are implementing practical and technical digital security measures but lack a strategic approach to digital security, based on risk management. Technical security measures are a widespread practice in German firms. However, only 34% of firms carry out a periodical digital security risk assessment considering the probabilities and consequences of security incidents (Figure 2.14), compared with 60% in Finland, the best performing country. The situation in SMEs is similar, with a vast majority implementing key technical measures, but only few carrying out more strategic activities, involving for example organisational measures and security related training (wik, 2017[136]).

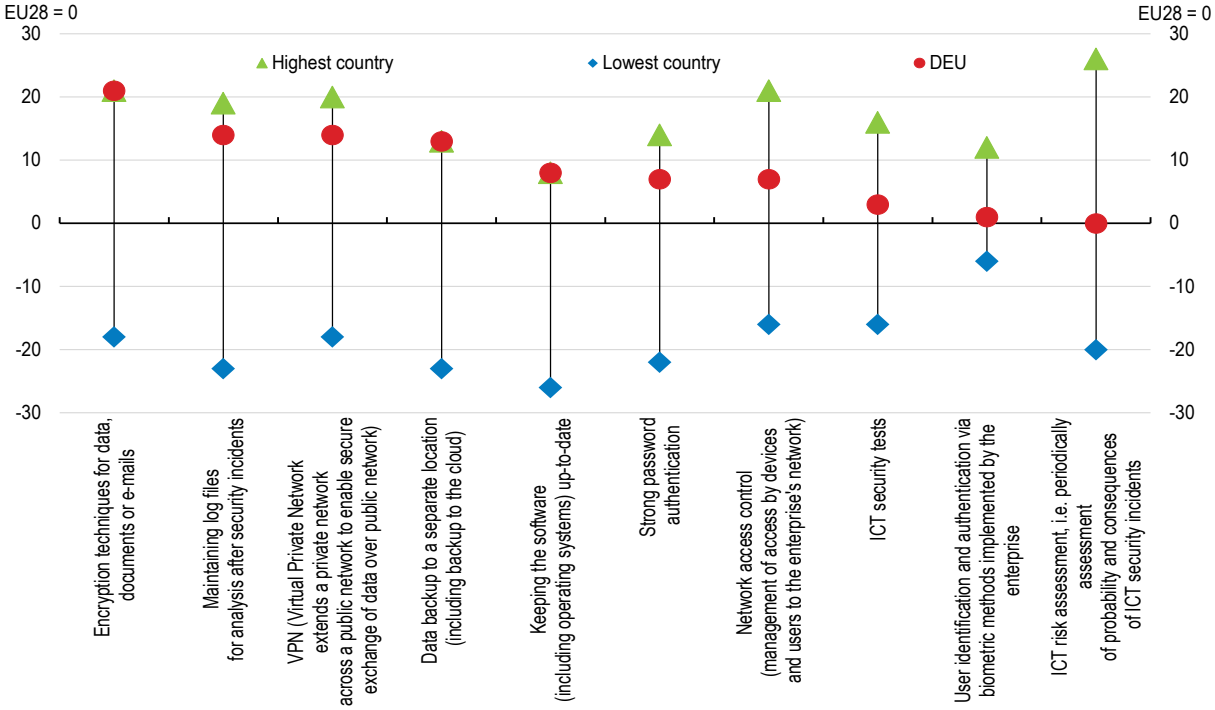
Risk assessment is an essential part of digital security risk management, which itself is the foundation for firms to approach digital security risk strategically and to increase resilience. Digital security risk management enables firms to prioritise resources not only to protect their information systems and networks from attacks, but also to reduce the effects of incidents on the business, for example, loss of reputation, theft of innovation assets, or disruption of operations (OECD, 2015[137]). Implementing digital security risk management in firms requires elevating digital security from being merely a technical issue to the top of business decision making. This involves raising awareness and empowering all stakeholders to understand and manage digital security risk, including via continuous risk assessment.

The government's current approach to digital security is focussed on legal, technical, and civilian aspects (Schallbruch and Skierka, 2018[138]) and lacks a strong business perspective and strategic promotion of digital security risk management in firms. While the 2016 Cyber-Sicherheitsstrategie für Deutschland (Cybersecurity Strategy for Germany) recognises the importance of protecting firms, it highlights in this

respect the role of the *Länder* police and the federal Verfassungsschutz (the domestic intelligence service of the Federal Republic of Germany) (BMI, 2016[139]). Both institutions are legitimately concerned with cybercrime and legal issues, but may not be well equipped to support firms in managing digital security risk for business success and resilience. A revision of the 2016 Cybersecrity Strategy for Germany should lead to a stronger focus on firms in general and on digital security risk management in particular, with the aim to foster economic and social prosperity (OECD, 2015[137]; BMI, 2016[139]). Such an approach can be found in the United Kingdom's National Cyber Security Strategy (HM Government, 2016[140]).

Figure 2.14. Despite strong technical measures, digital security risk assessment remains weak

% of the enterprises (10+ employees) implementing digital security measures 2019



Source: (Eurostat, 2018[34]).

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The Digital Strategy 2025 also addresses digital security in firms, however, it focuses mainly on legal and technical issues (BMWi, 2016[115]); the project GAIA-X too is primarily concerned with technical solutions (Box 2.5 above) (BMWi and BMBF, 2019[55]). While the programmes IT Sicherheit in der Wirtschaft (IT Security in the Economy) and Digital Now explicitly target firms and include measures to raise awareness, provide advice and offer other support related to digital security, in particular for SMEs (BMWi, 2020[141]; BMWi, 2020[142]; BMWi, 2020[127]), these practical measures seem largely independent from the 2016 Cybersecurity Strategy for Germany and insufficient for a more strategic promotion of digital security risk management in firms. In order to strengthen the business perspective and the digital security risk management approach in the Cybersecurity Strategy for Germany, closer co-operation may be required between the Federal Ministry of the Interior, Building and Community, which drafted the strategy, and the BMWi, which can provide relevant expertise and experience on digital security policies targeting firms.

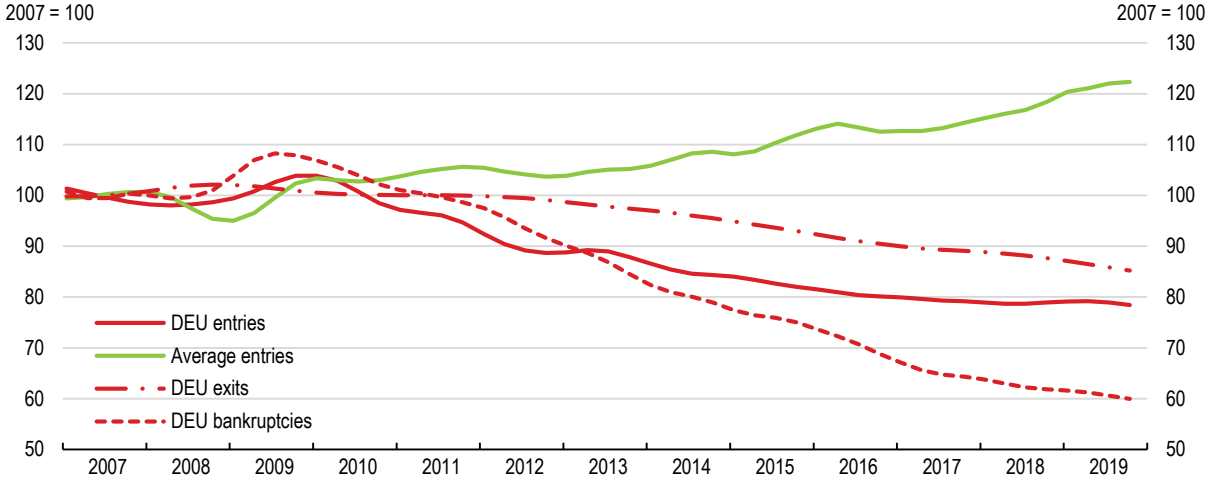
2.5. Supporting business dynamism during the recovery to boost technology diffusion

Business dynamism is essential for the diffusion of ICT tools and activities and for productivity. Policies that foster business dynamism have become even more important in the context of the COVID-19 crisis. This includes policies that favour reallocation and technology diffusion, notably measures that facilitate young and small firms' access to finance, restructuring and realignment of established firms, and the closure of non-viable firms (Sorbe et al., 2019[143]). In addition, digital government, notably digital public services, can facilitate firm creation and reduce administrative costs.

Misallocation of resources and unequal diffusion of ICT tools and activities have damped business dynamism and productivity across the OECD for some time. Business dynamism, as characterised by firm entries, exits, and job re-allocation, tends to be higher in digital-intensive sectors than in the rest of the economy, but declined in many OECD countries over the past 20 years, in particular in digital-intensive sectors (Calvino and Criscuolo, 2019[144]). Productivity growth also slowed in most OECD countries over the same period, affected by many factors, including the misallocation of resources (Adalet McGowan and Andrews, 2018[145]), unequal diffusion of ICT tools and activities and a divergence of productivity growth between frontier and laggard firms (Andrews, Criscuolo and Gal, 2016[146]). In Germany, there is also a gap between highly productive firms and others, in particular in services, though this gap did not widen between 2003 and 2014 (Schiersch, 2019[147]).

In Germany, business dynamism was losing momentum and draining productivity growth already long before the COVID-19 crisis. Contrary to the average across several OECD countries, entry rates in Germany are on a long-term decline, alongside decreasing exits and bankruptcies (Figure 2.15), and productivity growth slowed significantly over the past two decades (Sachverständigenrat, 2019[148]). Start-up activity is slowing in all sectors, including in knowledge-intensive industries and high-tech manufacturing (OECD, 2018[3]). Decreasing entry rates might partly reflect demographic trends, such as a shrinking share of the age group most likely to start a business (30-50 years), relatively high wages, and a tight labour market (European Commission, 2018[112]). However, other factors discussed below are important as well.

Figure 2.15. Business dynamism was slowing down long before the COVID-19 crisis



Note: Index constructed with business demography data. See here for more information on the methodology. "Average entries" includes data for Belgium, Denmark, Finland, France, Germany, Iceland, Italy, Japan, Netherlands, Norway, Sweden, and the United States.
Source: OECD, Timely indicators of entrepreneurship (ISIC 4). Data sources vary according to the country.

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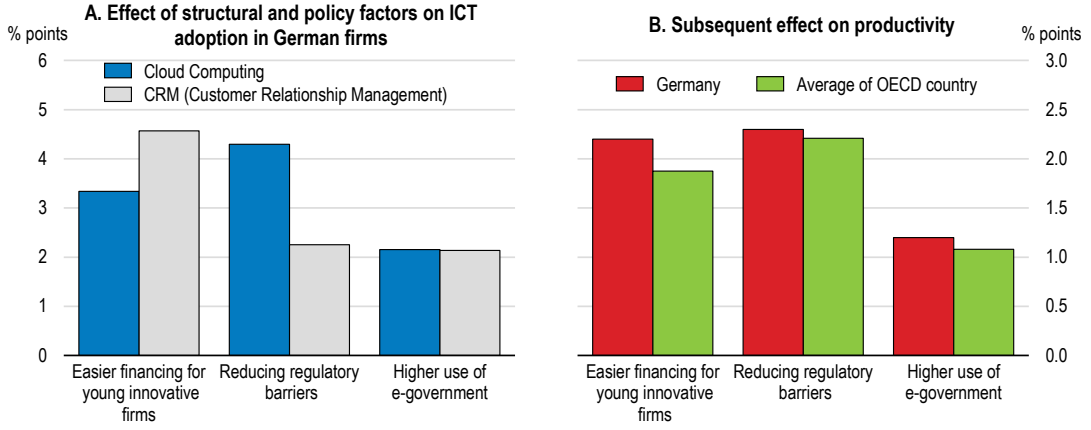
Multiple initiatives exist to facilitate business creation. Two online portals are targeting potential entrepreneurs, the Existenzgründungsportal and the Gründer Plattform, providing practical information on planning, financing and starting a business. The former features the start-up campaign GO! that promotes an entrepreneurial mind-set, strengthens relevant skills in schools and universities, and empowers women and migrants to start a business. The start-up contest Gründerwettbewerb – Digitale Innovationen rewards innovative digital business ideas, and the Digital Hub initiative operates twelve hubs across Germany that facilitate networking among start-ups, SMEs, science and administration in seminal industries. To kick-start international start-ups, a German accelerator was set up in Singapore and a second one is planned in India (BMWi, 2020[142]). These are well-targeted measures, but could potentially be more effective if bundled under a digital innovation agency or foundation, such as VINNOVA in Sweden or NESTA in the United Kingdom. The above measures are also unlikely to reverse the trend of declining business dynamism alone, without additional structural policies.

Key structural policy levers to revitalise business dynamism include measures to improve firms' access to start-up and growth finance, to reduce regulatory barriers, and to accelerate progress towards digital government. All three levers can have significant direct effects on the diffusion of ICT tools and activities, such as CRM and cloud computing, that in turn can support multifactor productivity growth (Figure 2.16). Such policies should be considered alongside policies to overcome key barriers to firms' successful digital transformation (Section 2.4) and policies to improve skills to thrive in the digital age (Section 2.6).

Figure 2.16. Policies supporting business dynamism, technology diffusion and productivity



Note: Estimated effect on the average adoption rate of selected ICTs (Panel A) and the multi-factor productivity (MFP) of the average firm (Panel B) of a range of policy and structural factors. For each of the underlying indicators, it is assumed that half of the gap to the best performing country in the sample is closed. It is also assumed that policy factors in each group are largely independent from each other.
Source: Based on (Sorbe et al., 2019[143]).

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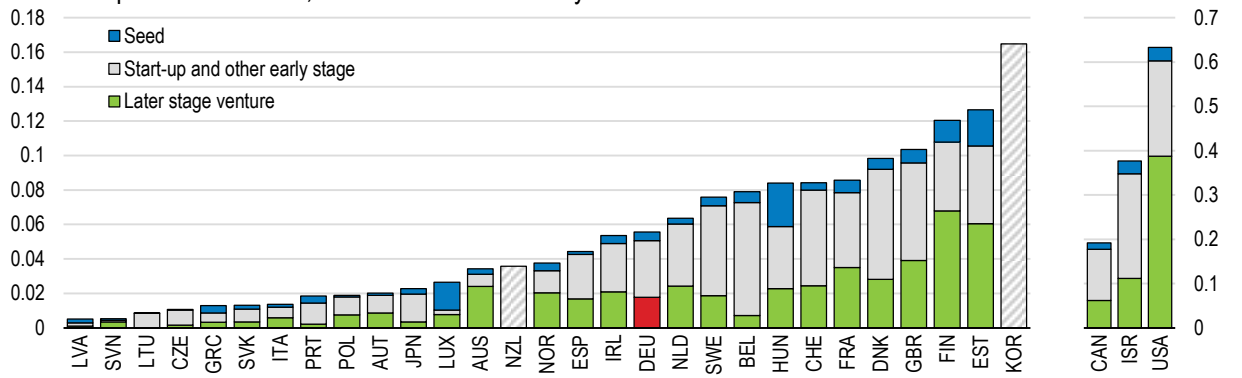
Improve access to start-up and growth finance

Access to finance at different development stages of a business, from creation to scale-up and growth, is a key ingredient for business dynamism. Among the range of available financing instruments, venture capital (VC) is essential to finance start-ups with high growth potential (OECD, 2019[149]). While an important non-official VC market through big firms' VC arms in Germany is not captured in official figures, internationally comparable VC investments are far below those in the best performing countries, in particular for seed and later stage funding (Figure 2.17). While between 2014 and 2019, VC as a share of GDP in Germany grew faster (19% per year) than on average (14% per year), and some German cities have become hot spots for start-up funding in Europe, notably Berlin (EY, 2019[150]), the current level is still below half of that in Finland and Estonia and at least 10 times smaller than in the United States.

Figure 2.17. Much potential remains for seed and later stage venture capital investments

Venture capital as % of GDP, 2019 or latest available year



Note: For Korea and New Zealand, no breakdowns of venture capital by stage are available.
Source: OECD Entrepreneurship Financing Database.

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Following the 2008 financial crisis, several countries maintained or created new equity support measures, including Canada, Chile, Denmark, Finland, France New Zealand, Sweden and the United Kingdom, which have arguably helped stabilise or grow VC investments since (OECD, 2020[151]). Germany also has a range of instruments to support seed and later stage funding. Key instruments targeting early stage start-up funding include the high-tech start-up funds, the INVEST and EXIST programmes, and a micro-mezzanine fund (BMWi, 2019[152]). Key instruments targeting later stage funding, predominantly financed by the ERP-Special Fund, include the venture capital fund Coparion, the joint ERP/European Investment Fund (EIF) VC fund of funds, the European Angel Fund Germany, the KfW Capital fund of funds programme ERP Venture Capital Fund investments, the ERP/EIF Growth Facility as well as the ERP/EIF/*Länder* Mezzanine fund of funds and the Tech Growth Fund including the KfW bank's Venture Tech Growth Financing-programme (BMWi, 2020[153]).

Further development of VC policy should aim to improve the effectiveness of existing instruments, including by avoiding complexity and by scaling up in particular later stage funding, for example through co-investment and fund of funds. One example is British Patient Capital, a subsidiary of the British Business Bank, which invests around EUR 3 billion in venture and growth capital alongside private sector equity funds, supporting a total of EUR 9 billion of investment over a decade (BBB, 2020[154]) (OECD, 2019[149]). The uptake of different instruments in Germany should be further monitored and improved where possible, taking feedback from beneficiaries into account, to address the lack of private VC.

A shortcoming of the German and European VC market is that institutional investors are only marginally involved, in particular compared to the United States, where 5% of pension funds' investment goes to start-ups (European Commission, 2018[112]). As a consequence and due to a stipulation by the ruling parties to establish an additional EUR 10 billion start-up fund for next generation technology, the government is considering strengthening the role of KfW Capital to become more active in growth financing and is examining approaches to make investment conditions more attractive to institutional investors (BMWi, 2020[142]). These efforts should be pursued further.

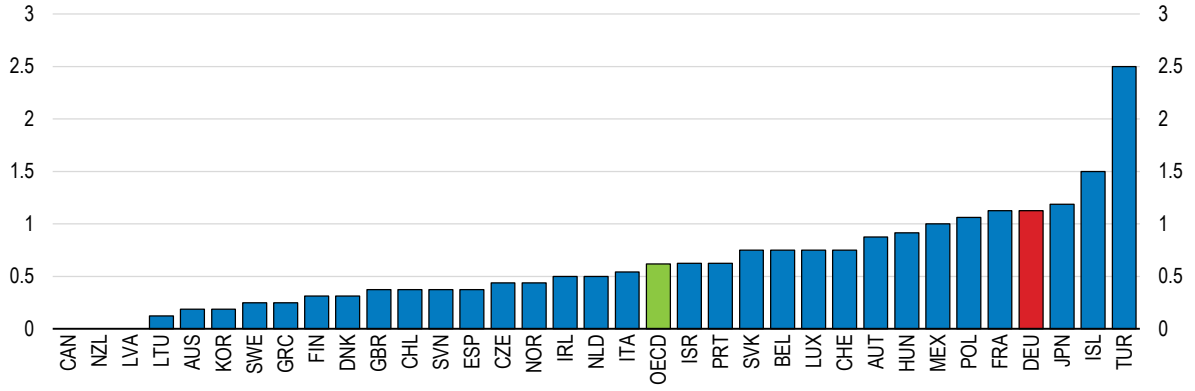
Reduce remaining bureaucratic burdens

Firms continue to perceive bureaucratic burdens in Germany as high and consider them a key barrier to growth. Almost half of all firms admit not implementing all bureaucratic requirements and focusing on the most important ones. This could weaken the effectiveness of the regulatory framework over time (IfM, 2019[155]). SMEs face the greatest difficulties, considering regulatory simplification and support for the implementation of digital transformation projects as key areas for improvements (IfM, 2018[156]).

Overall, administrative burdens for start-ups in Germany are low, compared to other countries. However, administrative requirements for limited liability companies and personally owned enterprises are still among the highest in the OECD (Figure 2.18). This notably concerns requirements to set up such enterprises (Vitale et al., 2020[157]). To start an enterprise in Germany, entrepreneurs have to make appointments with several different bodies, some of which require tedious paper work. Digitalising this process and providing a central online portal for the business creation online could help (bjdw, 2018[158]). In Estonia, entrepreneurs can create a business entirely online, even from abroad, a process that enabled 98% of companies to be established online and 95% to file online tax declarations (EAS, 2020[159]).

Figure 2.18. 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: Personally owned enterprises are business entities owned and run by one natural person and in which there is no legal distinction between the owner and the business. Limited liability companies that are not quoted on the stock market. The US and Estonia are not yet included in the PMR database. Information refers to laws and regulations in force on 1 January 2018 and for a few countries 1 January 2019. For federal countries, where matters are regulated at state level, the values reflect the situation in one state (selected so as to be representative).
Source: OECD 2018 PMR database.

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Reforms have eased some regulatory burdens, but more could be done to reduce one-time compliance costs. The “one-in-one-out” rule, which obliges the government to eliminate a bureaucratic burden each time it creates a new one, has proven successful so far. The third Bürokratieentlastungsgesetz (BEG III, law to reduce bureaucracy) has lowered regulatory burdens for firms by an estimated EUR 1.1 billion. However, the BEG III only applies to ongoing compliance costs, while one-time compliance costs are still high. From 323 new regulations introduced between 2011 and 2019, only 51 resulted in ongoing compliance costs, while they created over EUR 12 billion in one-time compliance costs for firms (NRCC, 2019[160]).

Potential also remains for improving stakeholder engagement (Vitale et al., 2020[157]) in developing primary laws and subordinate regulations, which decreased over the past years (OECD, 2019[161]; OECD, 2019[162]). ICT tools could be better used to systematically engage stakeholders, in particular firms, many of which are willing to engage and to share their experience and expertise (IfM, 2019[155]).

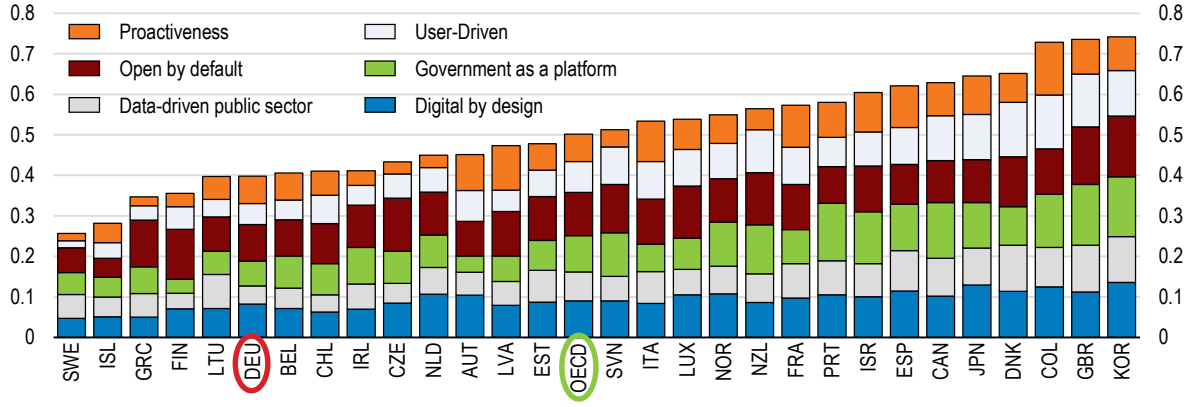
Accelerate progress towards digital government

To enable digital transformation across the economy and society, governments need to go digital themselves. For many countries, this implies an evolution towards a coherent and user-driven approach to digital government, guided by the needs of citizens and businesses (OECD, 2019[1]). While Germany has reinforced its efforts on digital government over recent years, much work remains to be done and priority should be given to accelerate the implementation of existing legislation and planned measures.

Germany performs below the OECD average on the OECD's Digital Government Index, a pilot exercise measuring digital government maturity (Figure 2.19). Germany notably lags behind on a data-driven public sector, which is characterised by using data to anticipate and respond to the needs of users and to deliver better services (OECD, 2019[25]). The government's forthcoming Data Strategy (Section 2.3) can play an important role in providing an effective framework for data governance also for a more data-driven public sector.

Figure 2.19. Germany lags behind on digital government

OECD Digital Government Index, 2019, score 0 to 1



Note: Data are not available for Australia, Hungary, Mexico, Poland, Slovakia, Switzerland, Turkey and the United States.
Source: OECD Survey on Digital Government 1.0.

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Integrated and user-driven digital public services are a key component of digital government and a lever for technology diffusion and subsequent productivity growth (Figure 2.16 above). Important potential remains to digitalise and improve public services in Germany. If paperwork was eliminated only for the most common service transactions, German companies would save EUR 1 billion in administrative cost (Stern et al., 2018[163]). Before the COVID-19 pandemic, the growth in the share of individuals and firms using the Internet to interact with public authorities was low and lagged behind many OECD countries (NKRG, 2019[164]; OECD, 2019[33]). Limited supply, lack of user- and mobile-friendliness and mistrust seem to constrain the number of interactions. For example, 7% of Germans do not submit completed forms online to public authorities because of unavailable digital services, four times more than in most other OECD countries (OECD, 2019[33]). Germany also performs below the EU average for basic online services for businesses, including service availability across borders (Figure 2.20).

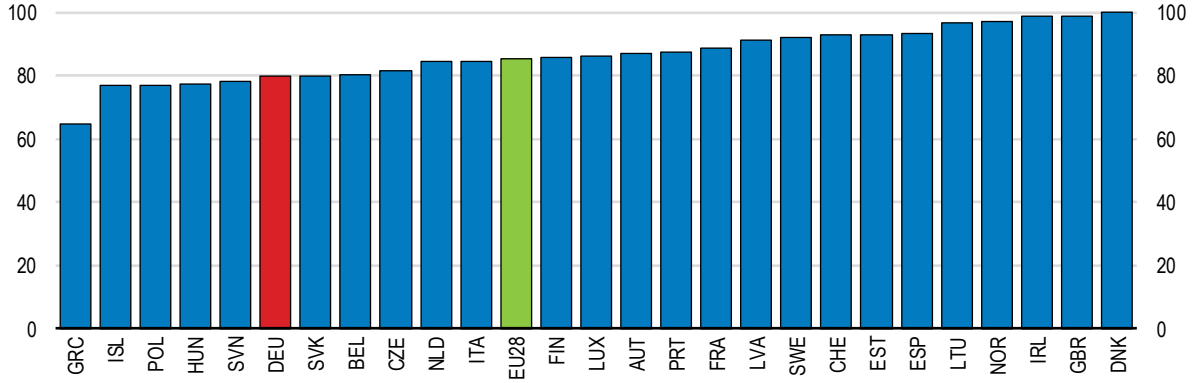
Germany's Online Access Act (OAA) mandates public administrations to offer their services digitally by 2022, with priority given to services with high demand and potentially large cost savings from digitisation. While the OAA is based on the principle of user-centricity, administrations currently use a variety of IT-systems that are not always interoperable, creating inefficiency and hindering user friendliness (Weilage and Chapters, 2018[165]). An important approach in the implementation of the OAA is the "one for all/many " model, which suggests that a digital service developed by one or more states should be made available to all other states. The objective is that the division of labour among states accelerates the implementation of the OAA and saves resources.

Nonetheless, authorities will have to collaborate better to meet the OAA's targets. Despite efforts of the IT-planning council to co-ordinate between federal and state levels on many digital government related issues (IT-Planungsrat, 2020[166]), and despite rising willingness to co-operate, challenges remain (NRCC, 2019[160]). A new institution (FITKO, Föderale IT-Kooperation) was founded in January 2020 to improve co-ordination. Its main objectives are to bundle the activities of the IT-planning council on digitising administration, manage the digitisation budget and serve as a knowledge and networking hub. As part of

the recovery package, an additional EUR 3 billion are earmarked (until the end of 2022) to accelerate the implementation of the OAA, improve the underlying IT-architecture and interoperability, and develop common standards. In the UK, to ensure efficient implementation, the UK's Service Manual is actively maintained by a team of content designers who work with the different professional communities (such as design, delivery and products) to document best practices and inform other teams throughout the public sector (OECD, 2020[167]).

Figure 2.20. Public services for businesses are not always available online and across borders

Digital government services for businesses, 2018, score 0 to 100



Note: The DESI eGovernment Services for Business indicator measures the degree to which basic public services for businesses, when starting a business and for conducting regular business operations, are online available and cross-border. This indicator is calculated based on the national, and cross-border online availability of the basic services Business life events (Regular business operations and Business start-up).
Source: European Commisssion, Digital Economy and Society Index Report 2019, https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=59975.

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Another key component of digital government is access to open government data, which can foster social participation, business opportunities and innovation. While the availability and accessibility of open government data have improved over recent years, and are close to OECD average, Germany still lags significantly behind most OECD countries in terms of policies supporting the reuse of open government data. The latter is due to limited monitoring of the impact of open government data and a lack of initiatives to promote data use and data literacy among civil servants in Germany.

Several actions could be taken to improve access to and reuse of open government data. The Open-Data-Gesetz (§12 of the e-government law) mandates federal authorities to release their data in open and machine-readable formats, free of charge, and with associated metadata on the federal metadata portal GovData.de. The last progress report on open data highlighted the need for a cultural change in public administration in the handling of data (Deutscher Bundestag, 2019[168]). This could be facilitated by raising awareness and improving the understanding of the potential of open government data across the administration, beyond the technical implementation of the law. Other countries were successful with targeted strategies. Ireland's National Open Data Strategy, Poland's Public Open Data Programme, and Slovenia's Public Administration Development Strategy are examples that have resulted in good progress in terms of open government data in recent years (OECD, 2019[169]). Further engaging in and leveraging open data-related partnerships, such as the Germany-Austria-Switzerland-Liechtenstein Cooperation and Code for Germany could also benefit greater reuse of open government data.

Germany has a large public procurement market, accounting for around 15% of GDP. From 2020, the use of electronic tools has become mandatory for all public supply and service contracts awarded by federal authorities and increasingly at the *Länder* level. This will result in cost reductions to bidders and the authorities and may improve project quality due to a broader distribution of winners, more of which are likely to come from outside the region where the work takes place (Lewis-Faupel et al., 2014[170]). E-procurement also facilitates the collection and use of procurement-related data, which in turn can help

to further improve procurement. Tapping into this opportunity requires systematic data collection and use, as well as digital integration of e-procurement with other public sector information systems (OECD, 2019[171]).

To ensure simpler, clearer and faster procurement of ICTs, Germany would benefit from establishing a digital marketplace for products and specialists. In the UK, such a marketplace is shaping how digital goods are procured and how expectations are set. Two different frameworks allow either cloud suppliers to list their goods, or public sector buyers to list their specific technology or skill needs, to which eligible suppliers can propose solutions (OECD, 2020[167]).

2.6. Improving skills to thrive in the digital age

The digital transformation of labour markets was in full swing even before the COVID-19 crisis and skills have become a key condition for people, firms and governments to thrive in the digital age (OECD, 2019[162]). The use of ICT in the workplace is now required in almost all occupations. Even employees who work outside the traditional office, like dairy farmers and car mechanics, have increased their use of ICT tasks and skills (Curtarelli et al., 2017[172]). The mix of skills that workers require includes foundational numeracy and literacy skills, science, technology, engineering and math (STEM) skills, ICT skills, as well as complementary skills (OECD, 2019[1]). Different policies are needed to address both short-term skill demand, such as signalled by labour market imbalances or training needs, as well longer-term supply, notably through education.

Foundational numeracy and literacy skills are in high demand

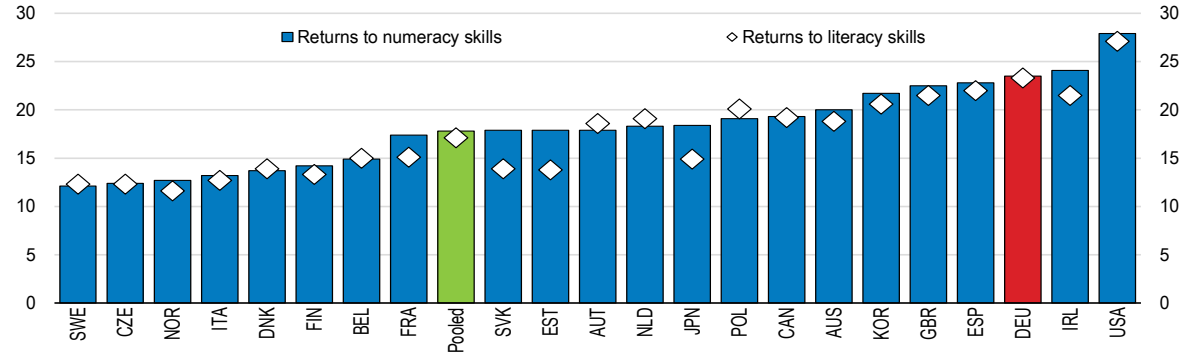
Workers in rapidly growing occupations, where ICT use and non-routine tasks are often more intensive, perform tasks involving reading, writing and numeracy more often (OECD, 2019[162]). Such foundational skills are also an important foundation for developing other, more specific, skills and competencies (Rammstedt et al., 2013[173]) and allow workers to adjust to new technologies and occupations more easily. Longer careers due to higher life expectancies and a large share of the service sector also heighten the importance of acquiring better foundational skills, including to better facilitate life-long learning. Adult proficiency in literacy, as measured in the OECD Programme for the International Assessment of Adult Competencies (PIAAC), is slightly below the OECD average. Adult proficiency in numeracy and problem-solving skills in technology-rich environments is slightly above the OECD average but lags behind leading countries. Reading performance of 15-year-olds declined in 2018, reversing the increasing trend of earlier years.

The impact of better foundational skills on relative earnings and probability of being employed is larger in Germany than in most OECD countries (Figure 2.21), which may reflect stronger specialisation on skill-intensive activities (Hampf, Wiederhold and Woessmann, 2017[174]; Fuentes Hutfilter, Lehmann and Kim, 2018[175]). In Germany, a one-standard deviation increase in numeracy or literacy skills is associated with about a 23 percent hourly wage increase. Advanced methods for calculating returns to skills indicate that the causal relationship may be even higher (Hampf, Wiederhold and Woessmann, 2017[174]). The impact of better ICT skills on relative earnings is of similar magnitude (Falck, Heimisch and Wiederhold, 2016[176]).

High returns to foundational skills signal that demand outstrips supply and that higher investment in such skills is economically worthwhile. More investment in early childhood education and schools to ensure individuals obtain strong foundational skills may also raise participation in adult education in the future since higher skilled individuals are more likely to participate in adult education (Desjardins, Rubenson and Milana, 2006[177]).

Figure 2.21. Returns to foundational skills are large

Percentage change in wages associated with a change of one standard deviation in proficiency in numeracy and literacy, after controlling for actual work experience and gender



Note: Least squares regressions weighted by sampling weights. Dependent variable: log gross hourly wage. Sample: full-time employees aged 35–54 (Canada includes part-time employees). Numeracy and Literacy score standardized to std. dev. 1 within each country. Pooled specification includes country fixed effects and gives same weight to each country. Sample: the 23 countries that participated in the first round of the survey (in 2011–2012).
Source: (Hanushek et al., 2015[178]).

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Better acquisition of foundational skills, especially for those with disadvantaged backgrounds, would also help reduce inequality and secure opportunities for upward intergenerational mobility. The gap in PISA results between advantaged and disadvantaged 15 year-old students is among the largest in OECD countries and increased since 2009 (OECD, 2019[118]). As the education system moves towards greater use of ICT tools, even more so after the COVD-19 pandemic, the gap between advantaged and disadvantaged students could increase further, as access to devices and parents' skill levels become more important.

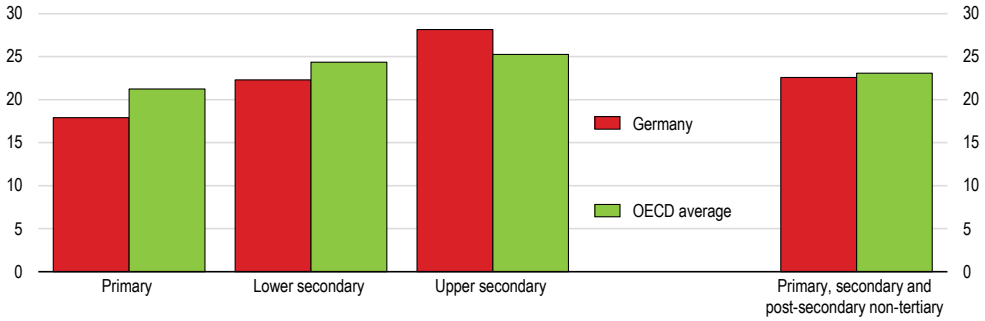
Prioritise early education and strengthen the foundational skills of VET graduates

For the digital age, it has become more important than ever to address inequality of opportunity starting at an early age. New technologies tend to complement skilled labour and replace low-skilled workers in the performance of routine tasks (OECD, 2019[162]). This effect is a prominent explanation for the rising wage inequality in many OECD countries since the 1980s, including Germany (Antonczyk, Deleire and Fitzenberger, 2010[179]). Investing in children's education at an early stage can produce high returns on investment since it creates a crucial foundation for future learning, especially for children with weak socio-economic backgrounds. Those who lack foundational skills are less likely to benefit from the opportunities of the digital transformation (OECD, 2019[162]).

Although the best period to acquire foundational skills is at early ages, spending on primary education and early childhood education is relatively low (Figure 2.22). Participation in early childhood education has increased rapidly over the past 15 years to just above the OECD average. Nevertheless, the quality of childcare is uneven. For example, there are differences in the staff-to-children ratio and in qualification levels (Fuentes Hutfilter, Lehmann and Kim, 2018[175]). Further improving professional development of day-care staff and monitoring the quality and standards of the educational institutions is therefore essential. Working with dual language learners is a top priority for professional development needs (OECD, 2019[180]). Improving access and quality of full-day schooling, as recommended in the previous economic survey, would be one way of prioritising primary education (Fuentes Hutfilter, Lehmann and Kim, 2018[175]).

Figure 2.22. While foundational skills are best acquired early, primary education spending is low

Total expenditure on educational institutions per full-time equivalent student relative to GDP per capita, 2016



Note: The graph uses data on the OECD Education at a Glance Indicators, Indicator C1: How much is spent per student on educational institutions?
Source: (OECD, 2019[181]).

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A complementary investment with more immediate returns would be to strengthen foundational skills of vocational education and training (VET) graduates. Thanks to the combined work and school-based programmes, Germany enjoys a very good integration of young people in the labour market. However, a trade-off seems to exist. The acquisition of occupation-specific skills at a relatively early age – at the expense of numeracy and literacy skills, and skills that facilitate continuous learning such as creativity and critical thinking – reduces later adaptability to changing environments. From the age of 45 individuals with a general education have higher employment probabilities in countries with the highest intensity of industry-based vocational education, including Germany (Hampf and Woessmann, 2017[182]). In Germany, people without a vocational education background also have higher salaries after about 8 years of labour market experience (Cörvers et al., 2011[183]). Research using data from the German microcensus found similar results. Additionally, it found that individuals completing a general education are more likely to acquire career-related education as they become older (Hanushek et al., 2017[184]). Rapid technological changes stemming from automation and digital transformation may make the obsolescence of occupation-specific skills even more pronounced (Krueger and Kumar, 2004[185]).

Ensuring that VET graduates have strong foundational skills is therefore essential. One way to provide them with these skills is to strengthen general education within the VET track, as the 2018 Economic Survey suggested (OECD, 2018[3]). To achieve this goal, one option could be to put more weight on mathematic and German skills in the final exams, which determine whether apprentices receive their formal VET qualification. This would increase motivation and highlight the importance of foundational skills, in particular for digital-intensive occupations. More time dedicated to strengthening foundational skills would also help students who are behind academically to find an apprenticeship (Bergseng, Degler and Lüthi, 2019[186]).

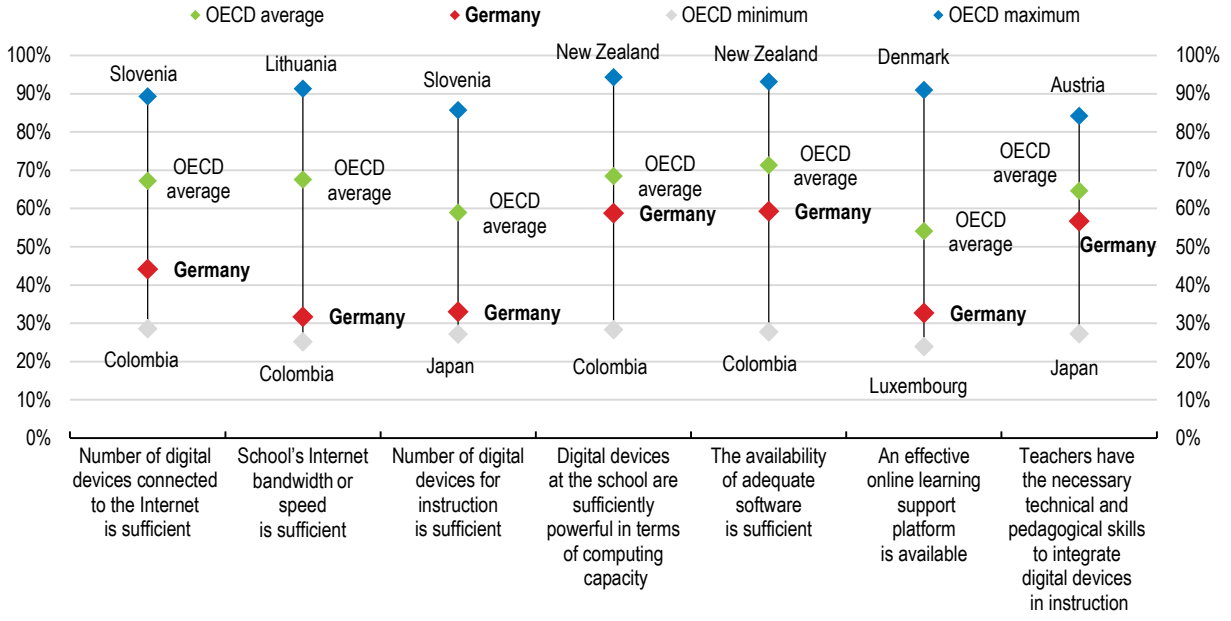
Postponing between-school tracking would be another way to strengthen foundational skills. In Germany, student selection for different programmes generally starts at the age of 10, compared with 15 or 16 in the majority of OECD countries. Therefore, low- and high-performing students are clustered in certain schools more often than the OECD average (OECD, 2019[118]). There is considerable international evidence that early tracking is associated with inequality in education, both in student performance and in the extent to which individual student achievement and other life outcomes reflect family background (OECD, 2016[187]). Nor is there any evidence of a positive effect of early tracking for the top students (Smidova, 2019[188]). The association between student performance and socio-economic background is significantly lower in Berlin and Brandenburg, where all primary schools are comprehensive until age 12, which does not come at a cost of lower average performance (Woessmann, 2009[189]).

Complement greater use of ICTs in schools with more ICT training for teachers

If teachers have the right skills, the use of ICT tools in schools and classrooms can help students develop skills for the 21st century and enhance student engagement. According to school principals' perceptions, Germany is lagging behind other OECD countries when it comes to the adequacy of ICT tools available in schools and the skills of teachers in using them effectively (Figure 2.23).

Figure 2.23. Germany lags on use of ICT tools in schools and teachers' preparedness

Percentage of students in schools whose principal agreed or strongly agreed with statements about the school's capacity to enhance learning and teaching using digital devices



Source: OECD calculations based on PISA (2018).

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As part of the DigitalPakt Schule, the federal government has allocated about EUR 6.5 billion to improve digital infrastructure, to provide all schools with a broadband connection and to equip all teachers and – if necessary – children with suitable devices. In practice, a year into the programme, disbursement was slow; accelerating disbursement is urgent in the current context of schools' increasing reliance on digital means to ensure continuity of education.

Extensive use of technologies at school needs to be combined with providing teachers with the necessary skills to use the new infrastructure, devices and software. The use of digital resources by teachers lacking appropriate skills, such as unfamiliarity with digital technologies, may distract and harm learning outcomes (OECD, 2019[190]). Teachers' lack of experience is also likely to make learning from home less efficient.

Investing in teacher training would help to improve students' skills and integrate ICT tools in teaching methods. In recent years, the federal government and the states increased efforts to strengthen initial teacher preparation (BMBF, 2019[191]). Improving ICT skills of the existing pool of teachers remains a challenge. Countries across the OECD have been tackling the need for ICT training through a range of policies, from introducing compulsory training to national accreditation standards or certification for teachers (OECD, 2019[162]) (Box 2.6).

Box 2.6. Policies for the development of teachers' ICT skills

Standardisation is one way that OECD countries improve teachers' ICT skills. Denmark, for instance, has developed a voluntary Pedagogical ICT Licence that combines pedagogical knowledge of ICTs and basic ICT skills training. After initial implementation for in-service training, this license was expanded to initial teacher education and general upper secondary education. While not mandatory, the licence is integrated into the curriculum of teachers who graduate from education colleges (OECD, 2019[162]).

Teachers' training can take the form of traditional face-to-face or on-line courses. In Spain, France, Slovenia, Sweden and the United Kingdom, courses on digital education tend to progressively develop into on-line training. In France, most of the digital skills training courses are provided on-line; and since 2014, 362,000 teachers were trained via digital platforms. Self-assessment tools may help teachers evaluate effectiveness and detect areas for improvement. In Finland, teachers can measure and analyse their use of ICT in teaching through an online self-assessment tool. It provides teachers, school and municipalities representatives information on how their ICT usage compares to others (European Commission, 2019[192]).

Integrating digital technologies into national testing could encourage teachers (and students) to enhance their ICT skills. In Finland, the national final test for upper secondary education has been gradually digitalised, becoming fully digital in 2019 (European Commission, 2019[192]). Additionally, Finland created 2 500 temporary mentoring positions to assist teachers in using new technologies and to promote using digital environments (European commission, 2018[193]).

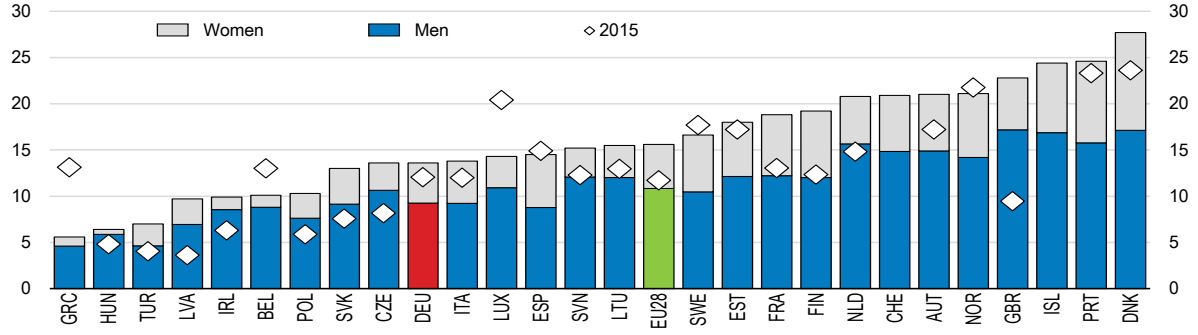
Source: (OECD, 2019[162]); (European Commission, 2019[192]); (European commission, 2018[193]).

Computational and programming skills need to improve, notably among women

Computational thinking and programming skills continue to gain importance, and curricula should be updated accordingly. Since the mid-1990s, the share of computer scientists within the STEM occupations increased dramatically (Spitz-Oener, 2018[194]). In 2017, 12% of 20-24 year-olds in Germany undertook a programming activity in the preceding 12 months, compared with just 3% of the population aged 45-54. However, Germany lags behind most EU countries in this domain and has hardly progressed since 2015 (Figure 2.24). The gender gap is particularly noticeable. Women comprised 32% of 16-24 year-old programmers, compared with about 38% in Finland, Denmark and Spain. Like many EU countries, Germany recently reformed the national curriculum related to digital competences. However, the strategy does not include programming as part of the learning objectives, in contrast to most EU countries (European Commission, 2019[192]).

Figure 2.24. A low share of young adults are able to program

16-24 year-old individuals who can program, % of all Internet users aged 16-24, 2019



Source: OECD Going Digital Toolkit, https://goingdigital.oecd.org/en/indicator/54/.

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Introducing computational thinking to the majority of students at early stages of education would empower people and underpin competitiveness of the German economy. When students are exposed to computational thinking through programming, they can increase both their problem-solving and digital competencies, as well as acquire a deeper understanding of the underlying mechanisms and concepts of new technologies. France introduced a mandatory upper secondary school course on computational sciences and technology in 2019 (OECD, 2019[162]). In the near future, the priority could be to improve computational thinking, rather than programming specifically, as computational thinking can be integrated into many subjects and be taught by the current pool of teachers.

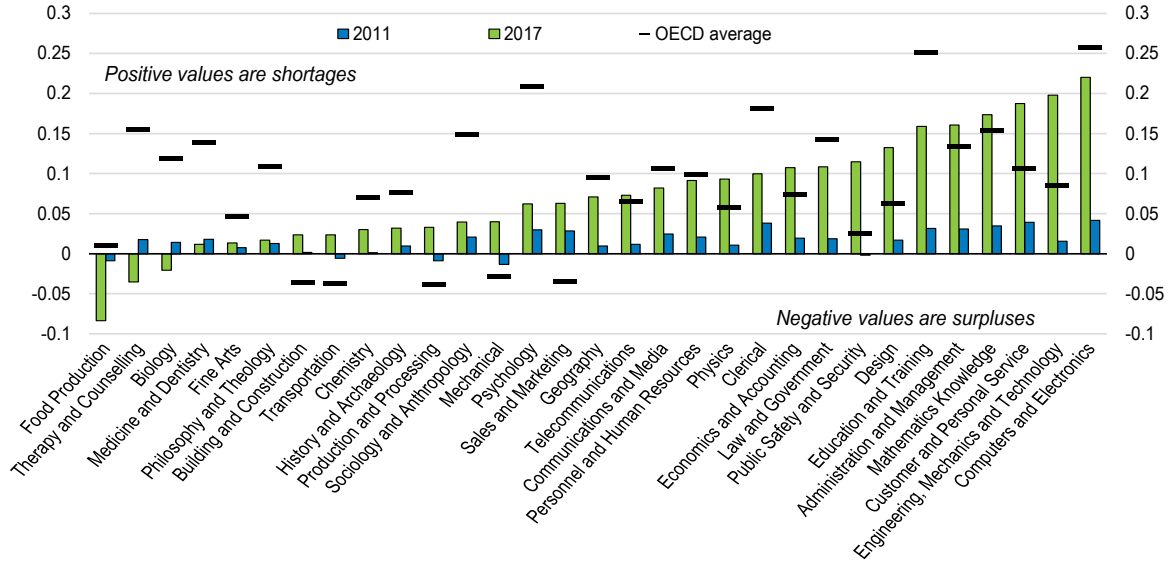
Positive early experience with programming may also help reduce gender gaps. A recent study found that giving first-grade girls an opportunity to try programming increases their interest in technology and self-efficacy, and that this experience eliminated related gender differences (Master et al., 2017[195]). In Italy, a coding course targeting female middle-school students resulted in a 10% increase in participants' interest to become a computer programmer (Carlana and Fort, 2020[196]).

Increasing opportunities to study STEM and ICT-related fields

Prior to the COVID-19 pandemic, the most prominent skills shortages were in computers and electronics, engineering and mathematics, with more severe shortages in 2017 than in 2011 (Figure 2.25) even though the migration of workers with these skills has increased significantly (Anger et al., 2020[197]). These knowledge domains are closely associated with Science, Technology, Engineering and Mathematics (STEM) fields of study. Adults with a tertiary degree in engineering, manufacturing and construction and those with a degree in ICT related fields earn about double compared to those with upper secondary education, one of the highest premiums among OECD countries (OECD, 2019[181]). Because demand has outpaced supply for these skills, the STEM premium has increased since the mid-1990s, for both men and women (Spitz-Oener, 2018[194]).

Figure 2.25. Significant shortages exist in STEM related knowledge domains

Knowledge domains that are in shortage and 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 the analysis of the wage growth, employment growth, hours worked growth, 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 skills 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 skills for jobs database.

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In addition, demand for ICT specialists was picking up and enterprises reported growing difficulties in filling vacancies before the COVID-19 pandemic. From 2012 to 2018, the number of persons employed as ICT specialists grew by 20%, 2.8 times the increase in total employment. However, the share of ICT specialists in total employment in Germany is still below the EU average. Supply constraints seem to prevent a greater increase. In 2018, more than two thirds of enterprises searching for ICT specialists reported recruitment problems, up from less than half in 2014. Skills shortages cause wage increases. Between 2001 and 2016, wages of workers in the ICT sector rose by 35% compared with a 25% increase in total labour productivity (OECD, 2017[198]).

The limited supply of STEM graduates and ICT and data specialists is slowing the adoption of new technologies and hampering innovation. The employment of ICT specialists in firms, for example, is strongly associated with the adoption of key ICT tools and activities (Table 2.2) that underpin digital transformation and data-driven innovation. The limited supply affects in particular SMEs, which may help explain why SMEs have not increased R&D expenditure over the past decade (Weilage, 2018[199]). The skill shortage suggests that incentives to invest in R&D, without complementary actions to increase skills supply, will not be enough for firms to benefit from digital transformation, and may instead just increase the wages of the existing pool of workers.

Table 2.2. ICT specialists are essential for firms' adoption of key ICT tools and activities

Estimated percentage point changes in the adoption of ICT tools and activities for German firms by employment of ICT specialists and provision of IT training to their employees

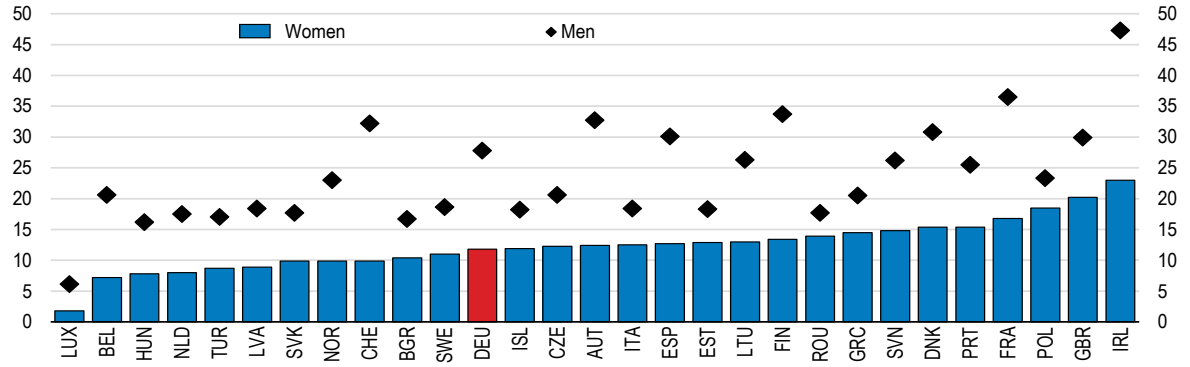
	ERP	CRM	e-purchase	e-sales	Social media	Cloud computing	BDA
Employment of ICT specialists	10.668***	7.185***	5.423***	6.284***	9.403***	6.141***	3.561***
IT training of employees	10.012***	7.835***	8.015***	4.581***	3.027***	5.631***	3.221***
Observations/Firms	24685/22316	24593/22241	24857/22467	30126/26511	26330/22724	9488/8546	5821/5821
Survey years	2012-2015, 2017	2012, 2014, 2015, 2017	2012-2015, 2017	2012-2017	2013-2017	2014, 2016	2016

Note: Firms with 10 or more employees, excluding financial sector. This table reports OLS regression results based on a representative micro-data sample of German firms. Coefficients reflect the percentage point increase in the likelihood of a firm adopting a given ICT tool or activity associated with employing ICT specialists or providing IT training to employees. In addition to a broad set of control variables, regressions (except big data) control for year, municipality and industry (4 digit) fixed effects. Big data uses fixed effects at the county level instead of the municipality level. Table A1 in the Annex provides additional detail. Standard errors clustered at the municipality level (not reported); ***, ** and * denote significance at the 1%, 5% and 10% level, respectively. ERP stands for enterprise resource planning, CRM for customer relationship management, and BDA for big data analysis.
Source: (Alipour, forthcoming[14]).

Increasing opportunities to study STEM and ICT-related fields at universities and technical colleges is key to tackle skills shortages in the long-run. Although Germany's share of STEM graduates among tertiary graduates is one of the highest in the OECD, the share of STEM graduates (of all ages) per 1000 population aged 20-29 is lagging behind leading EU countries, especially for women (Figure 2.26). The share of tertiary ICT graduates is lagging behind leading OECD countries as well (OECD, 2019[33]). The STEM Action Plan, introduced in 2019, aims to raise enthusiasm to take up STEM education and careers. Networking, funding and communication measures that are part of the plan are focused especially on girls' and women's needs.

Figure 2.26. The share of STEM graduates lags behind leading countries

Graduates in tertiary education, in science, mathematics, computing, engineering, manufacturing, construction, per 1000 of population aged 20-29, 2018



Source: Eurostat, education and training (educ) database.

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Easing the transition between educational systems may increase accessibility. Despite significant reforms, the route from post-secondary VET to academic higher education remains rarely travelled (Fazekas and Field, 2013[200]; OECD, 2019[181]). Further use of bilateral credit transfer systems between technical colleges and universities would be one way to facilitate those transitions. Increasing supply of interdisciplinary ICT related programmes could help to increase the participation of women. There are relatively high shares of German women in studies such as bio-informatics, media informatics and medicine informatics (empirica, 2019[201]).

Shorter programs may help reallocate furloughed employees and fresh graduates to occupations and sectors in higher demand. In Estonia, for example, supply was boosted by a programme allowing postgraduates to earn a bachelor degree in programming by attending a six-month software developer programme. In Germany, the post-secondary VET institutions could supply these kinds of programs. This approach equips people holding valuable prior experience and knowledge with digital knowhow. Such multidisciplinary skills may be valuable both to the ICT sector and traditional sectors, and may help build better links between the two (OECD, 2019[202]). Immigration from third countries can also increase the supply of talented workers.

A change in gender-specific perceptions about ICT occupations would help increase the supply of STEM graduates and ICT specialists, and decrease the gender pay gap. Women made up just 18% of ICT specialists in 2018, and the share of women among engineers is similar. Wages for engineers and ICT specialists are high for both men and women, and the gender pay gap for those who work as ICT specialists is below that in most occupations (Wrohlich and Zucco, 2017[203]). One reason for the lower gender pay gap is greater flexibility in working hours and work location (Goldin, 2014[204]). Even before the COVID-19 crisis, about 75% of ICT workers in Germany frequently or occasionally worked from home, the highest share among all occupations except teaching (Alipour, Falck and Schüller, 2020[205]).

Making female role models more visible, fighting gender stereotypes and providing girls with opportunities to interact with technology at the earliest ages could help change gender-specific perceptions about ICT (OECD, 2019[206]). At 15 years of age, only 0.8% of girls wish to become ICT professionals, compared with 6.6% of boys (OECD, 2019[206]). Society, notably parents and teachers (Carlana, 2018[207]), may convey stereotypes and social norms that influence choices about the future. Campaigns advocating for choices free from gender stereotypes, such as the Cliché Free Initiative since 2016, are therefore welcome. A higher likelihood of women dropping out of STEM (Vom, Isphording and Qendrai, 2019[208]) highlights the importance of enhancing persistence, alongside efforts to raise motivations to enter STEM fields. Women already in STEM may benefit from same-gender mentoring (Dennehy and Dasgupta, 2017[209]), learning communities (Russell, 2017[210]) and alternative teaching methods.

Encourage low-skilled individuals to take part in adult education

Although adults with low skills are most at risk of experiencing deteriorating labour market prospects, they are less than half as likely to participate in adult learning as those with higher skills. This may reflect lower returns on investment in training, in part due to poor foundational skills that impair the capacity to learn and to apply adult learning. Employers returns may be especially low as they risk losing employees to competitors, after they have invested in their skills (OECD, 2003[211]). Another reason for lower participation may be that adults with low skills find it more difficult to recognise their learning needs and hence are less likely to seek out training opportunities (Windisch, 2015[212]).

Nevertheless, the social returns of life-long learning for adults with low skills are likely to be higher because it may help reduce unemployment benefit claims and other transfer spending for low-income households, and boost inclusive growth (OECD, 2018[213]). In the course of the digital transformation, further learning among low-skilled adults could increase the social returns further, as it supports the adjustment process and thus prevents structural unemployment (IAB, 2019[214]). Additionally, the association between training and faster adoption of key ICT tools and activities is stronger for low- than for high-skilled workers (Andrews, Nicoletti and Timiliotis, 2018[215]).

Outreach through the workplace can be effective in engaging adults in learning (OECD, 2019[216]). Counselling and assistance for businesses, especially SMEs, can help identify suitable training, and, hence, increase motivation and alignment with future needs. The government recently took steps in this direction with the Qualifizierungschancengesetz (Skills Development Opportunity Act) (BMAS and BMBF, 2019[217]). Trade unions can provide a bridging function between employers and employees with low skills, who might be hesitant to communicate their training needs to employers (OECD, 2019[216]).

Life-long learning measures are essential to build and adapt skills over time and should be informed by systematic identification of skills and training needs. Career counselling is an essential element of Germany's approach to accompany the workforce throughout their entire educational and working life with professional advice and orientation. The Work of Tomorrow Act (Arbeit-von-Morgen-Gesetz), from 2020, aims to facilitate adult learning through increased financial support and decreased bureaucratic efforts for employers and employees. Such measures are most effective if they are linked to systematic identification of skills and training needs, such as in the Portuguese initiative on digital competences 2030 (Box 2.7).

Better validating uncertified skills including those acquired on the job, as suggested in the last survey (OECD, 2018[3]), can boost incentives to participate in adult education and help workers adjust to new technologies. Skill recognition can shorten the path to qualification, reducing costs for learners. Over two million Germans aged between 20 and 34 do not have any certified vocational qualifications (BMAS and BMBF, 2019[217]); and migration flows create a pool of workers with unrecognised skills. Migrants with a foreign qualification in Germany are at least three times more likely to be overqualified for their job compared with native peers, even when they have similar literacy skills. In most OECD countries, the gap between migrants and natives is lower. Further steps to reduce duration of apprenticeship for those who have relevant experience may help decrease the number of workers with unrecognised skills. This will only be successful if all stakeholders, including employers, benefit from recognising workers' skills. A different apprentice wage scale over the shortened duration of the apprenticeship may be a way to ensure support of employers (Kis and Windisch, 2018[218]).

Box 2.7. The Portuguese National Initiative on Digital Competences 2030

The Portuguese National Initiative on Digital Competences 2030 (INCoDe.2030) aims to broaden digital literacy, promote employability and professional training in digital technologies and raise participation in R&D networks. INCoDe.2030 takes a broad view of digital competences, including skills to effectively use ICTs and manipulate data as well as communication and digital content production skills.

INCoDe.2030 includes initiatives to identify needed digital competences as well as measures to facilitate training and labour market inclusion. It offers citizens to benchmark their level of skills and identify knowledge gaps on a dynamic framework based on the European initiative DigComp 2.0. Specific programmes are designed to target vulnerable groups, including via a freely accessible online training platform. The programme also includes life-long learning and active labour market programmes to help displaced workers integrate in a dynamic labour market.

Source: (OECD, 2020[7]).

The government recognised the challenges facing skills policy with the National Skills Strategy in 2019. The strategy aims to reorganise all of the federal and state training programmes, align them with market needs and establish a new training culture. Additionally, it aims to improve training statistics and improve counselling services, existing support systems, quality assurance and the visibility of skills acquired through informal learning. Furthermore, it extends support for workers who are affected by structural changes regardless of their qualifications, and develops educational institutions into centres of excellence for continuing vocational education and training.

Reap the potential of online education as a universal learning tool

ICT tools can improve accessibility, flexibility and quality of adult learning. Open education and massive open online courses enable people of all ages to study anytime and anywhere. These courses are usually free, or very cheap, and often provided by universities, including many top ones. However, use of these tools is low. In 2012, only 5% of Germans participated in open or long-distance education, compared with 9% on average among OECD countries. The share in Korea, a country with a considerable experience with open education, is close to 20% (OECD, 2019[162]). Widely available high-speed Internet, co-operation between key government agencies in supporting ICTs in education, and a big education market contribute to enable Koreans to participate in digital learning. During the COVID-19 crisis, Korea has provided a virtual training platform that enables learning providers to upload their course content, supported by subsidies and quality assurance mechanisms (OECD, 2020[219]). The UK introduced a Skills Toolkit, an online platform that brings together free online courses in a variety of areas, including digital skills, digital marketing and coding (HM Government, 2020[220]).

For those who complete online courses, certification and/or recognition remains a challenge (OECD, 2019[1]). To get certification right, it is crucial for the government to co-operate with education and training providers, employers, job-search agencies and social partners to reap the full potential of open education as a universal learning tool. Stringent skill certification tests would decrease employer uncertainty and improve the benefits to new workers (Kässi and Lehdonvirta, 2019[221]).

MAIN FINDINGS	RECOMMENDATIONS (key recommendations in bold)
Developing a national digital transformation strategy	
Germany has multiple digital related strategies and distributes responsibilities for digital policies across line-ministries, with only ad hoc or light co-ordination of digital matters.	Develop a comprehensive national digital transformation strategy that integrates and/or co-ordinates other digital related strategies and policies, led by a ministry or body with a strong mandate for co-ordination.
Addressing connectivity bottlenecks and increasing quality of service	
A very low share of fibre results in low broadband speeds. Public funds for broadband deployment have been disbursed slowly.	**Shorten administrative approval times for communication network deployment, including obtaining rights of way, and improve co-ordination between public authorities.**
There is a high concentration in the fixed broadband market with two companies owning more than 70% of fixed broadband connections.	Facilitate passive infrastructure sharing and increase the transparency of information on existing passive infrastructure such as ducts. Carefully monitor competitive dynamics in the German fixed broadband market and foster competition and investment in the connectivity of multi-dwelling buildings.
Germany has fewer mobile broadband subscriptions than the OECD average and falls behind in data usage and connection speeds.	Implement the Mobilfunkstrategie according to schedule. Increase the availability of public assets for the deployment of mobile infrastructure. Streamline obtaining rights of ways and administrative procedures.
The entrance of a fourth player to the mobile market has the potential to promote competition and innovation.	**Support competition through facilitating that the market entrant can obtain national roaming agreements. Consider all market participants when existing spectrum licenses expire**. Ease and promote infrastructure sharing while ensuring an adequate level of infrastructure competition.
Strengthening foundations for firms' digital transformation	
Firms lag behind in adopting key ICT tools and activities for the data economy, notably SMEs and firms in small and remote municipalities. Firms could also use more data from their own sensors and devices for big data analysis.	Ensure that the forthcoming *Data Strategy* provides an effective data governance framework to enhance access to and sharing of data, including in the public sector, and helps firms to boost their collection and effective use of (firm-related) data.
Digital transformation creates opportunities and challenges for the automotive industry, in particular in autonomous driving and shared urban mobility.	Strengthen standard-setting related to autonomous driving technologies through a strategic and co-ordinated approach across standardisation bodies, consortia and industry domains.
Overcoming key barriers to firms' successful digital transformation	
Firms' investments in knowledge-based capital that is crucial for data-driven innovation, including software, databases, and organisational capital, are low and have hardly increased over the past decade.	**Improve conditions for firms to invest in knowledge-based capital, including by reviewing the cap for R&D tax incentives to make them more applicable to mid-range companies.**
SMEs are behind large firms on digital transformation and would benefit from greater adoption of advanced ICT tools and activities and from more investment in complementary intangible assets.	Accelerate SMEs' digital transformation by swiftly implementing existing SME support, increasing it if needed, and ensuring that investment incentives for physical capital do not discourage expenditures on digital services.
Digital security concerns retard the adoption of key ICT tools and activities; too few firms carry out continuous risk assessment; the cybersecurity strategy lacks a strong business perspective based on digital security risk management.	Promote digital security risk management by firms through a revised national cybersecurity strategy; raise awareness and empower all stakeholders to understand and manage digital security risk, and incentivise continuous risk assessments in firms.
Supporting business dynamism during the recovery to boost technology diffusion	
Venture capital investments as a share of GDP are much lower than in best performing countries, in particular for seed and later stage funding.	Improve the effectiveness of start-up and growth financing instruments, including by avoiding complexity, scaling up later stage funding and improving conditions for institutional investors to invest in venture capital.
Certain bureaucratic burdens for firms remain high, notably one-time compliance costs and burdens to start a business; scope also remains to improve stakeholder engagement in regulatory policymaking.	Consider one-time compliance costs when revising the *Bürokratieentlastungsgesetz* (law to reduce bureaucracy); use ICT tools to simplify the administrative process of business creation and to improve stakeholder engagement in regulatory policymaking.
The share of individuals and firms interacting with public authorities online is growing only slowly and Germany lags behind on open government data; the now mandatory e-procurement could be further improved.	**Accelerate progress towards digital government and a data-driven public sector, focusing on high-impact services, collaboration across levels of government and open government data, and systematically collect and use data from e-procurement processes.**
Improving skills to thrive in the digital age	
Strong numeracy and literacy skills help people adjust to new technology. Their impact on earnings and employment is higher in Germany than in most OECD countries, reflecting high demand for such skills.	Prioritise early education by increasing spending on primary education, and improve foundational skills of VET graduates, for example by strengthening general education within the VET track or postponing between-school tracking.
The use of ICT in schools lags behind most OECD countries and computational thinking and programming skills have much scope to improve, in particular among women.	**Increase ICT training for teachers to ensure effective use of ICTs**. **Introduce computational thinking earlier (particularly benefitting girls) while avoiding gender stereotypes in education and career guidance.**
Before the COVID-19 pandemic, demand for ICT specialists and programming skills was picking up: wages grew rapidly and enterprises were reporting more difficulties in filling vacancies.	Raise accessibility of STEM and ICT fields of study, for women in particular, by easing the transition between post-secondary educational systems, establishing learning communities and encouraging same-gender mentoring.
Adults with low skills are less likely to participate in adult learning, although their jobs are at higher risk of change due to digital transformation.	Facilitate participation of low-skilled individuals in adult education by taking further steps to validate uncertified skills, including those acquired-on-the job, and through workplace outreach.

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Annex A.

Annex Table 1. Correlations in the adoption of ICT tools and activities

Estimated percentage point change in the likelihood of adopting ICT tools and activities for German firms by speed tiers of broadband subscription, ICT skills and training, and other characteristics

	ERP	CRM	e-purchase	e-sales	Social media	Cloud computing	BDA
Internet speed tiers							
<10 Mbps (baseline speed)							
Broadband 10-30 Mbps	0.925	-0.008	1.814**	1.322*	2.966***	1.520	-0.236
Broadband 30-100 Mbps	1.604*	2.057**	2.568***	2.867***	6.613***	6.962***	-1.201
Broadband 100+ Mbps	3.317***	3.073***	1.122	4.321***	9.747***	6.850***	3.074**
ICT skills and training							
ICT specialists employed	10.668***	7.185***	5.423***	6.284***	9.403***	6.141***	3.561***
IT training to employees	10.012***	7.835***	8.015***	4.581***	3.027***	5.631***	3.221***
Other characteristics							
Size	7.999***	2.903***	2.902***	5.064***	4.780***	2.335***	2.443***
Multi-plant	-0.277	0.251	0.951	-0.031	2.079**	5.097***	-0.388
State-owned	0.355	-4.991**	-0.964	-4.738***	-6.961***	-5.124**	-2.283
Listed	0.001	1.771	1.462	3.527**	8.980***	3.611	6.085*
Controls							
Regional controls	x	x	x	x	x	x	x
Municipality FE	x	x	x	x	x	x	
County FE							x
Industry FE (4-digit)	x	x	x	x	x	x	x
Year FE	x	x	x	x	x	x	
Observations/Firms	24685/22316	24593/22241	24857/22467	30126/26511	26330/22724	9488/8546	5821/5821
Survey years	2012-2015, 2017	2012, 2014, 2015, 2017	2012-2015, 2017	2012-2017	2013-2017	2014, 2016	2016
Adjusted R-squared	0.34	0.15	0.06	0.23	0.22	0.10	0.07

Note: Firms with 10 or more employees, excluding financial sector. ERP stands for enterprise resource planning, CRM for customer relationship management, BDA for big data analysis. This table reports OLS regression results based on representative repeated cross-section survey data of German firms for the period 2012-2017. Dependent variables equal 100 if a given ICT tool or activity is adopted and 0 otherwise. For Internet speed tiers, coefficients reflect the percentage point change in the likelihood of a firm adopting a given ICT tool or activity associated with broadband speed tiers of 10-30 Mbps, 30-100 Mbps and 100+ Mbps, respectively compared to a baseline speed of <10 Mbps. For ICT skills and training, coefficients reflect the percentage point change in the likelihood of a firm adopting a given ICT tool or activity associated with employing ICT specialists or providing IT training to employees. Regional controls include the following municipality-level variables: Log of number of inhabitants, share of working age population (ages 15-64), share of people aged 65+, employment rate, log of area in sqkm, share of university graduates (measured at the county level). For Big data (surveyed only in 2016) additional controls account for the remoteness of the municipality (travel time by car to nearest international airport and to higher-order centre) and the years since the introduction of basic broadband (> 256 Kbps) in the municipality. Additional firm controls include: Size (log of number of employees) and indicators identifying whether a firm is state-owned, listed or multi-plant, respectively. Standard errors are clustered at the municipality level (not reported); ***, ** and * denote significance at the 1%, 5% and 10% level, respectively.
Source: (Alipour, forthcoming[14]).

Endnotes

[1] Digitisation is the conversion of analogue data and processes into a machine-readable format.

[2] Digitalisation is the use of ICT tools and data as well as interconnection that results in new or changes to existing activities.

[3] Under article L. 34-8-3 of the Post and Electronic Communications Code ("Code des postes et des communications électroniques", CPCE), introduced by the Law of the Modernisation of the Economy ("Loi de modernisation de l'économie", LME) in 2008.