GERMAN COUNCIL
of Economic Experts

PRODUCTIVITY GROWTH THROUGH INNOVATION: ADVANCING DIGITALISATION

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PRODUCTIVITY GROWTH THROUGH INNOVATION: ADVANCING DIGITALISATION

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This is a translated version of the original German-language chapter "Produktivitätswachstum durch Innovation: Digitalisierung vorantreiben", which is the sole authoritative text. Please cite the original German-language chapter if any reference is made to this text.

KEY MESSAGES

- Private innovation spending in Germany is concentrated among large companies. Incentives for innovation and diffusion at small and medium-sized enterprises should be strengthened.
- Germany is well positioned in the development of digital technologies, but the framework conditions for digital services and business models should be improved.
- The pandemic has highlighted deficits in the digitalisation of public administration, healthcare and the education system. These should be reduced quickly and consistently.

SUMMARY

Roughly 65 per cent of the long-term growth in labour productivity in Germany can be attributed to growth in total factor productivity (TFP). The innovation process in an economy plays a key role for the TFP development. The **innovation process** includes the research and development of new products and technologies, their transformation into marketable innovations and their diffusion throughout the economy.

From a macroeconomic perspective, there is generally too little investment in the innovation process, especially because of positive knowledge externalities and funding constraints. **Public engagement** in the innovation process can counter this trend by supporting research at universities and research institutes, by transferring knowledge and technology to the private sector and by supporting private-sector innovation activity. One-third of research and development spending in Germany is currently funded by the public sector and two-thirds are funded by the **private sector**. Private innovation spending in Germany is increasingly concentrated on large firms. Innovation spending at small and medium-sized enterprises is fairly modest as a proportion of their revenues. There are **barriers** to **accessing skilled labour** and innovation funding. The low availability of **venture capital** in comparison with other countries is also likely to hinder the formation and growth of innovative start-ups.

Particularly **substantial potential** for raising productivity across the entire economy is currently offered by **general-purpose technologies in the field of digitalisation**, which can be applied in many different economic sectors. While Germany plays a leading role in the EU when it comes to digital innovation, it lags behind worldwide leading nations such as the US and South Korea. Much still needs to be done to ensure the diffusion of digital technologies within firms and public institutions as well as the development of digital and data-driven business models.

The coronavirus pandemic has triggered a surge in digitalisation, which should now be harnessed. There is a need to invest more in digital infrastructure and dismantle bureaucratic barriers to its expansion in order to accelerate the **diffusion of digital technologies** and facilitate new business models. At the same time, it is important to increase the teaching of **key digital skills** in schools and through lifelong learning opportunities. In order to **strengthen Germany's innovation environment** it might be appropriate to expand the European Research Area further, **improve the transfer of knowledge and technology**, make **public-sector data** available for the development of business models, and embed **innovation criteria** more firmly **in the public procurement process**. The digitalisation of administration could provide significant demand stimulus. In order to encourage digital innovation and start-ups, the **European digital single market** should be deepened, the availability of private venture capital should be increased and the competition rules – for example with respect to data interoperability and portability – should be modified to ensure the **competitive openness of digital markets** and the contestability of entrenched positions of market power.

I. PRODUCTIVITY GROWTH THROUGH INNOVATION

481. In keeping with its statutory mandate as the National Productivity Board, the German Council of Economic Experts (GCEE) analyses, among other things, the factors that affect steady productivity growth. The Productivity Report 2019/20 identified lower growth in the capital stock and the declining growth in total factor productivity (TFP) as the main causes of the decrease in hourly productivity growth observed in Germany since 1960 (GCEE Annual Report 2019 items 144 ff.). The GCEE's medium-term forecast predicts that the average annual trend growth rate for TFP over the next five years will be 0.5 % and will thus remain at a low level. ↘ ITEMS 88 FF. The **focus** of **this year's National Productivity Report** is therefore on the German economy's **innovation process** and its impact on productivity growth.

482. The innovation process includes **research and development (R&D)**, the development of marketable **innovations** and the **diffusion** of new products and technologies. Basic research is conducted mainly at publicly funded research institutes. ↘ ITEMS 494 FF. Its translation into innovations – although partly funded by the state – is primarily driven by private actors. Small and large firms perform different functions in this process. ↘ ITEMS 502 FF.

The development and **use of general-purpose technologies** are especially important because they can raise productivity throughout the whole economy. Digitalisation offers considerable potential that has yet to be exploited. ↘ ITEMS 524 FF. Whereas innovation activity tends to decline during recessions, the redesign of processes necessitated by the coronavirus pandemic – especially those in the field of digitalisation – could drive the use of new technologies and the development of innovations. ↘ ITEMS 545 FF.

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The first step in the **typical innovation process** is the **invention.** Inventions are brought about by R&D activities, which comprise the "creative and systematic work undertaken in order to increase the stock of knowledge [...] and to devise new applications of available knowledge" (OECD, 2018). R&D activities comprise basic research and applied research, which are undertaken in order to acquire new knowledge, as well as experimental development, which is directed to producing new products or processes or to improving existing products or processes. **Innovation** – as distinct from invention – is characterised by the transformation into new products offered in the market and into processes used by the firm that differ substantially from previous products offered or processes used by the firm, and it is often based on inventions (OECD and Eurostat, 2019). Innovation activities include all activities undertaken to develop an innovation, and thus also include R&D activities. As the concept of innovation relates to the novelty of a product or process for the firm concerned, innovations can also include the integration of processes already used or products already produced by other firms. This spread of new processes and products throughout the economy is referred to as **diffusion** (Rogers, 2010).

Productivity as the engine of growth

483. **Growth in TFP** accounts for the largest share of growth in hourly productivity and, consequently, the largest share of growth in **gross domestic product (GDP)** per capita – in relation to the total population (GCEE Annual Report 2019 items 145 ff.). ↘ CHART 73 Growth in TFP is measured as the change in GDP that cannot be explained by changes in labour and capital inputs. An increase in TFP can be attributable to either technological progress or to improvements in the allocation of factors of production in the economy (Jones, 2016). The quantitative growth contribution made by TFP is determined by a growth decomposition, which splits per-capita GDP growth into its components of growth in the volume of labour, growth in capital intensity, and growth in TFP.

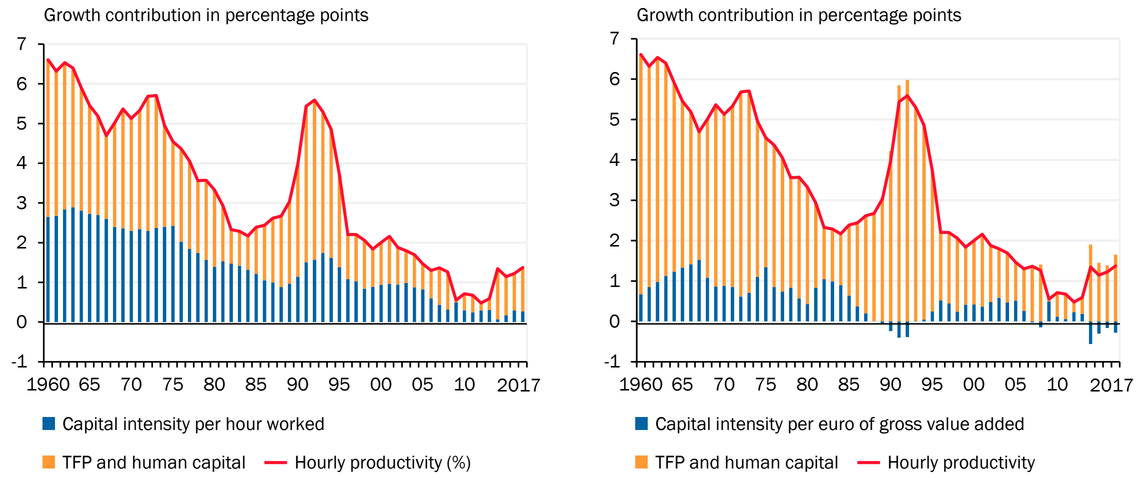
484. The classic **growth decomposition** method attributes growth in hourly productivity to the direct contributions made by the components **capital input** per hour worked and **total factor productivity**. This decomposition method shows that between 10 % and 30 % of the growth in hourly productivity in Germany during the period from 1960 to 2017 can be attributed to increases in TFP. ↘ CHART 73 LEFT Growth in TFP also provides an incentive to invest and, therefore, indirectly raises hourly productivity as well (Klenow and Rodríguez-Clare, 1997; Jones, 2016). If we include this indirect contribution, between 60 % and 80 % of the growth in hourly productivity in Germany during this period can be attributed to TFP growth. ↘ CHART 73 RIGHT

↘ CHART 73

The most important component of growth in hourly productivity in Germany is TFP growth

Growth decomposition of hourly productivity into direct contributions ...

... and including indirect contributions



1 – Total factor productivity. Five-year moving averages. 2 – The indirect TFP contribution includes the contribution made by increases in the capital stock per hour worked, which is induced by growht in TFP. Calculation method according to Jones (2016).

Sources: Feenstra et al. (2015), Penn Word Table Version 9.1, own calculations

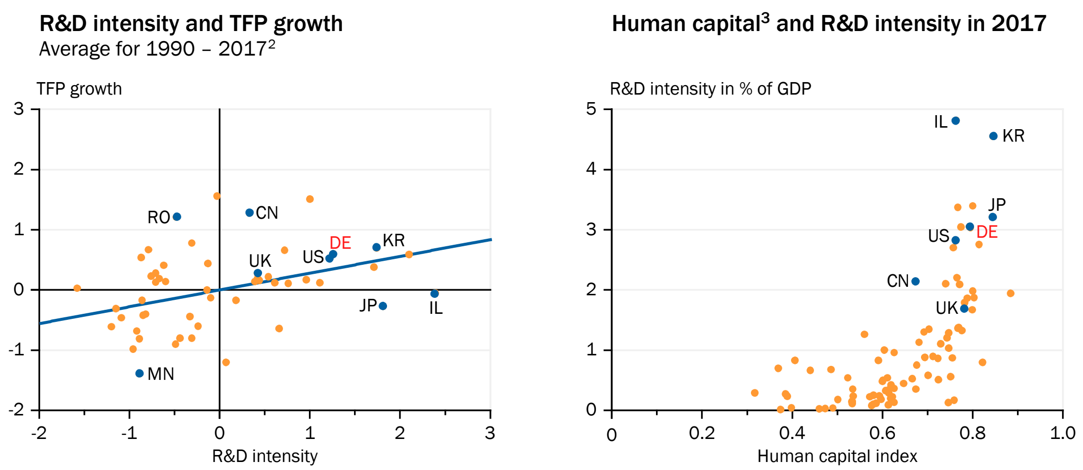
TFP growth as a measure of technological progress

485. Growth in TFP shows a positive correlation with R&D indicators. ↘ CHART 74 LEFT This is confirmed by Westmore's (2013) empirical analysis of 19 OECD countries during the period from 1986 to 2008, which shows a statistically and economically **significant positive correlation between innovation indicators** such as R&D intensity or patent applications **and TFP growth** at the aggregate level. TFP growth is therefore usually interpreted as a measure of technological progress. A more disaggregated analysis also reveals a positive correlation between TFP and measures of innovation.

The change in productivity measured at the macroeconomic level arises from changes in productivity at the sectoral and firm level and from the reallocation of factors of production and market share between firms and sectors. The **positive correlation** between **R&D**, **innovation activity** and **changes in productivity at the firm level** has been comprehensively documented. There is also evidence of positive externalities impacting on firms' productivity as a result of R&D spending by other firms in the same product area or technology field and in related sectors (Griliches, 1998; Hall et al., 2010).

486. The **strength of the correlation between innovation activity and TFP growth** depends on further factors. It decreases, for example, as market entry costs and insolvency costs rise (Égert, 2017), and it increases in line with the number of researchers as a proportion of total employment, which might be explained by a greater capacity for knowledge absorption (Westmore, 2013).

↘ CHART 74
Positive correlation between R&D intensity, TFP growth and human capital[1]



1 – Research and development (R&D), total factor productivity (TFP); CN-China, DE-Germany, IL-Israel, JP-Japan, KR-Republic of Korea, MN-Mongolia, RO-Romania, UK-United Kingdom, US-USA. 2 – Adjusted in each case for the gap between the respective country's TFP and the US's TFP. The slope of the regression line is 0.279 for a t-value of 2.85. The R^2 of the regression is 0.138. 3 – The index measures the amount of human capital that a child born today can expect to have by the age of 18, given the healthcare and education systems of the country concerned. It is intended to illustrate how improvements in current healthcare and education outcomes affect the productivity of the next generation of workers. It is assumed that children born today will, over the next 18 years, experience the educational opportunities and health risks to which children in this age group are currently exposed.

Sources: Feenstra et al. (2015), OECD, Penn World Table Version 9.1, World Bank, own calculations

On the whole, the level of education is an **important factor** for an economy's **innovativeness** and productivity because a well-educated workforce is a key input for research, development and innovation activities (Benhabib and Spiegel, 1994; Aghion, 2008; Aghion et al., 2009). At the aggregate level, there exists a strongly positive correlation between national human-capital indicators and the national R&D share. ↘ CHART 74 RIGHT There is also a positive correlation over the short and long term between patenting activity and measures of human capital (Dakhli and De Clercq, 2004; Diebolt and Hippe, 2019).

Innovation and its diffusion

487. The innovations based on R&D activities are typically **product innovations** – i.e. improvements of existing products or the development of new products – and **process innovations**, which result in lower production costs. Other forms of innovations are **marketing innovations** and **organisational innovations**, which give rise to revenue increases for the same factor input or lead to cost reductions. More than 60 % of firms in Germany introduced or implemented at least one of these types of innovation during the period from 2015 to 2017. ↘ ITEM 504

488. Most innovation activities involve the introduction of processes or products that are new for the firm concerned but are already well-established at other firms. ↘ ITEM 509 This **diffusion process** is of considerable importance for the productivity performance of the economy as a whole (Atkeson and Kehoe, 2007; Comin and Mestieri, 2014). We can therefore see positive productivity effects as a result of the growing diffusion of digital technologies (Cardona et al., 2013) such as broadband internet (Czernich et al., 2011) and robots (Graetz and Michaels, 2018).

489. It is often necessary to equip employees with new knowledge and to reconfigure work processes and organisational structures in order to ensure that innovations diffuse properly and the full potential of new technologies can be realised. **Complementary investment** and the **adaptation of structures and processes** are therefore key determinants of the diffusion of technologies among firms (Brynjolfsson and Hitt, 2000; Bresnahan et al., 2002; Bloom et al., 2012). Differences in the human capital stock between firms and between countries can explain differences in their use of new technologies (Riddell and Song, 2017). Especially in the case of technologies involving network effects such as information and communications technology (ICT), it is also necessary to make the complementary infrastructure available so that firms invest in the technologies that build on these. ↘ ITEM 571

490. Both **R&D** spending and investment in the use of new technologies vary over the course of the **business cycle**. From a theoretical perspective, there are various drivers at play here, and it is unclear whether these investments in total vary procyclically or counter-cyclically (Aghion and Saint-Paul, 1998). It has empirically been shown that spending on R&D and innovation typically rises during boom phases and falls during recessions at both the aggregate level (Barlevy, 2007) and at a sectoral level (Ouyang, 2011). In addition to R&D spending, other innovation

indicators such as the **adoption of technology** behave pro-cyclically (Comin and Gertler, 2006; Anzoategui et al., 2019). The **number and quality of business start-ups** also behave pro-cyclically (Moreira, 2016; Sedláček and Sterk, 2017). ↘ ITEM 518

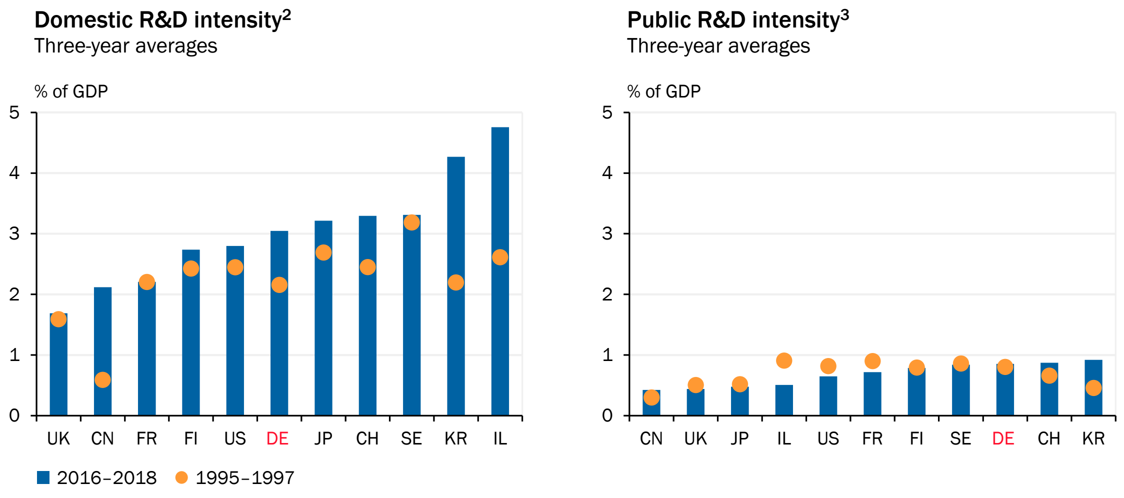
II. THE IMPORTANCE OF THE INDIVIDUAL ACTORS IN THE GERMAN INNOVATION SYSTEM

491. The particular characteristics of R&D and innovation activities can imply that the private innovation efforts of an economy remain inefficiently low. Knowledge that arises from R&D and innovation activities is not depleted once it has been used and could therefore, **in principle, be used by all market participants**. In order to strengthen innovation incentives, property rights such as patents and licences therefore ensure that the innovating firms benefit financially from the R&D that they carry out. However, the financial benefit for these firms is less than the benefit that the economy as a whole derives from their activities because, firstly, the benefit that consumers derive from new products is not fully internalised by the innovating firms themselves and, secondly, other firms often benefit from positive **knowledge externalities** despite the protection offered by patents. The incentive for firms to invest in research is therefore too low from a macroeconomic perspective (Jones and Williams, 2000; Bloom et al., 2013; Schnitzer and Watzinger, 2020).

492. It is also **difficult to use external funding** to finance R&D projects (Hall and Lerner, 2010; Kerr and Nanda, 2015). R&D projects involve a high degree of uncertainty, and information about the profitability of these projects is asymmetrically distributed between firms and lenders. At the same time, innovations cannot usually be collateralised. A large proportion of the investment provided for R&D projects takes the form of salaries paid to research staff, and realisable collateral such as patents is only generated if the project is a success. It is therefore often difficult to resort to the commonly used solution to the problem of asymmetric information of using collateralised loans.

493. The fact that innovation activity is too low from a macroeconomic perspective justifies the special role that the public sector plays in the **innovation system** (Freeman, 1987; Nelson, 1993). Between roughly one-quarter and one-third of R&D spending in many developed economies is funded by the public sector. Its share of GDP has either stagnated or even decreased in many countries over the past 30 years. ↘ CHART 75 RIGHT The rise in domestic R&D shares in many countries can therefore be attributed to higher private R&D spending. ↘ CHART 75 LEFT In order to implement its Lisbon Strategy, the European Council decided in 2002 to raise R&D spending in the EU to 3 % of GDP by 2010. To implement its ‘Europe 2020’ follow-up strategy it decided in 2010 to raise R&D spending in the EU to 3 % of GDP by 2020. The R&D ratio in Germany has now exceeded this 3 % target and

↘ CHART 75
Rising R&D intensity in Germany while public R&D intensity remains stable[1]



1 – Research and development (R&D) expenditure in relation to GDP. UK-United Kingdom, CN-China, FR-France, FI-Finland, US-USA, DE-Germany, JP-Japan, CH-Switzerland, SE-Sweden, KR-Republic of Korea, IL-Israel. 2 – Three annual values are not always available for the following countries: Sweden no value for 1996 and Switzerland no values for 1995, 1997, 2016 and 2018. 3 – Publicly funded R&D expenditure. Privately funded research at universities is not included. Spending on R&D staff, such as professorships or research group leaders, is counted as part of R&D expenditure in proportion to the working hours spent directly on R&D activities. Three annual values are not always available for the following countries: Sweden no value for 1996, 2016 and 2018, Switzerland no values for 1995, 1997, 2016 and 2018, France and Israel no value for 2018; for China no values are available for 1995-1997, so the first available value in 2000 has been used.

Sources: OECD, own calculations

amounted to 3.13 % in 2018. The German government has set a new target of achieving an R&D ratio of 3.5 % of GDP by 2025 (BMBF – German Federal Ministry of Education and Research, 2018).

1. Research and development at public research institutes

494. The market imperfections that justify public investment in research institutes apply especially to **basic research**. The knowledge externalities that arise here are particularly large, and the findings and insights gained do not usually possess any direct market applicability. The **public funding of basic research** is already very **well developed** in Germany. In addition to the universities there are various non-university research institutes and funding organisations that focus on basic research and make a valuable contribution in this field (GCEE Annual Report 2019 items 298 ff.). The non-university research institutes include the Max Planck Society, the Helmholtz Association of German Research Centers and the Leibniz Association, while the funding organisations include the German Research Foundation (DFG).

495. Private investment in **applied research** – in other words the link between basic research and market launch (Leyden and Menter, 2018) – may be too low from a societal perspective. This area is also publicly funded. As far as applied research in Germany is concerned, the **Fraunhofer Society** performs a key function and is regarded as a role model internationally (Intarakumnerd and Goto, 2018; Kang,

2019). **Universities of applied sciences** also engage in applied research. Like universities, they can have a positive impact on regional innovation activity (Lehnert et al., 2020).

496. The **transfer of knowledge and technology** from research institutes to firms in Germany remains in need of improvement (EFI, 2019). Only 38 % of the experts surveyed as part of the Global Entrepreneurship Monitor in 2019 view the relevant transfer conditions as being either good or fairly good (Sternberg et al., 2020). **A number of obstacles** can impede this transfer (Bozeman, 2000; Bozeman et al., 2015). A key influencing factor are the rules on **intellectual property** with respect to the findings of government-funded research. The ability to licence research findings and patents can accelerate the commercialisation of research. In this case, the owners of copyrights and patents allow firms to use and exploit their research findings in return for payment of a licence fee. At the time of licencing, however, many university research findings are still at the development stage and need to be developed further (Jensen and Thursby, 2001). Licencing offers an opportunity here to facilitate collaborations between firms and researchers. If user rights are exclusively granted to individual firms, however, this can discourage research activities for subsequent innovations.

497. In 1980 the Bayh-Dole Act in the United States introduced a standard procedure for **licencing** the findings of government-funded research, which grants the **usage rights** for resultant **patents** to the universities and considerably simplifies the licencing process. In the wake of this and further initiatives, the amount of patenting and licencing activity at US universities has increased significantly since the early 1980s (Henderson et al., 1998; Mowery et al., 2001).

A network of government-funded **patent commercialisation agencies** has been set up in Germany since 2001 as part of the country's **patent commercialisation initiative**. These agencies act as autonomous service providers in commercialising the patents for university inventions. In line with the Bayh-Dole Act the so-called **Hochschullehrerprivileg (university lecturers' privilege)** was **abolished** in 2002, which means that the rights to inventions are no longer owned by the university employees themselves but by the universities concerned. Consequently, the costs and risks associated with licencing are borne by the university. Between 2008 and 2015 the patent commercialisation initiative was continued by the SIGNO programme and, since 2016, it has been continued by the WIPANO programme. Under these programmes the funded universities and research institutes receive financial support during the process of patenting and patent commercialisation. They only receive funding if they collaborate with a patent commercialisation agency. The aim of these reforms and funding programmes is to create patent commercialisation incentives, to stimulate and improve the efficiency of knowledge and technology transfers and to unlock universities' intellectual resources (Cuntz et al., 2012; Kulicke et al., 2014, 2019).

498. Despite these initiatives, the number of **patent applications for university inventions** has **fallen** since 2000. One possible explanation for this decrease might be that universities are focusing on publication intensity, which is more im-

portant for their reputation and for researchers' career prospects. And, unlike patent intensity, publication intensity has indeed risen sharply (Cuntz et al., 2012; Kulicke et al., 2019). What is striking, however, is that even the number of patents that have resulted from collaborations between universities and firms has declined (Cuntz et al., 2012). However, the number of patents arising from **academic spin-offs** has not decreased (Tischler and Walter, 2014).

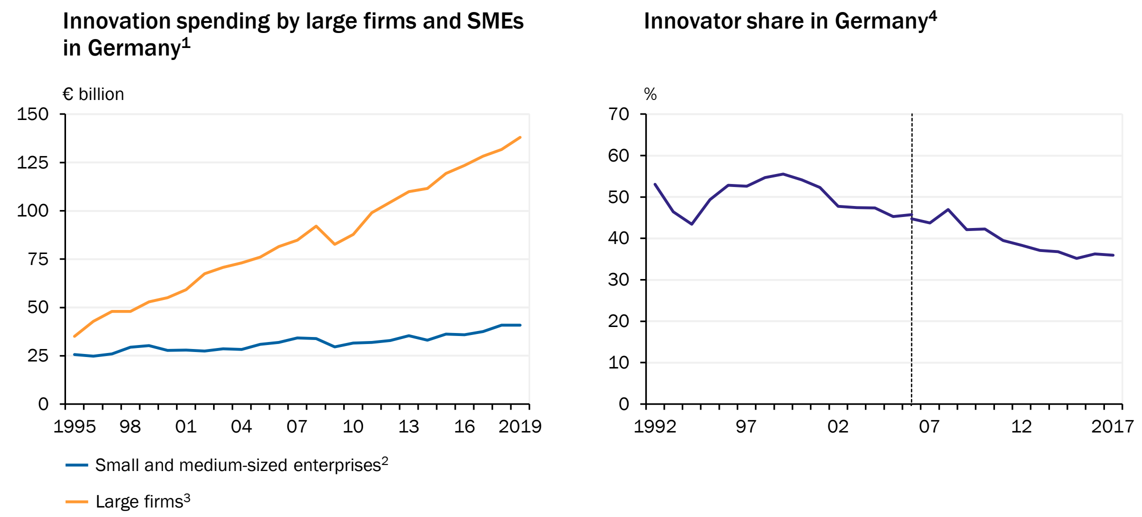
499. **Spin-offs** from research institutes and universities can be a **channel** for strengthening the **transfer of knowledge and technology** and are an important source of regional growth in the United States (Shane, 2004). Universities benefit directly from the firms' success in the form of patent royalties and direct investments. Stanford University and Harvard University either founded or invested in 22 and 14 start-ups respectively last year. They signed 119 and 45 licencing agreements respectively. In 2019 the Massachusetts Institute of Technology (MIT) either founded or invested in 25 start-ups and signed 112 licencing agreements. Globally successful innovation clusters such as Silicon Valley in the field of computer science and Kendall Square in the field of biotechnology developed in geographical proximity to these universities. Outside the United States and Germany, institutions such as Imperial College London, ETH Zurich, EPF Lausanne and Israel's Weizmann Institute of Science are regarded as best-practice examples of technology transfer.

500. The **Stifterverband's Start-up Radar** ranking (Frank and Schröder, 2018) has documented a rising number of start-ups at German universities between 2012 and 2017. These start-ups occur mainly in fields such as IT services and medical, environmental, climate and energy technology. According to those surveyed, roughly 43 % of such start-ups relate to transfers of knowledge or technology from universities, and 13 % are based on specific property rights.

Funding plays a key role in start-up activity at universities. The vast majority of universities have managed to improve the support they provide to start-ups in recent years. Valuable contributions have been made by the EXIST programme (EXIST Business Start-up Grant), which is funded by Germany's Federal Ministry for Economic Affairs and Energy (BMWi), and by the StartUpLab@FH programme, which was initiated by the Federal Ministry of Education and Research (BMBF). Students and graduates are involved in more than 50 % and 43 % of all start-ups respectively, while academic staff are involved in only around 20 % (Frank and Schröder, 2018). Most spin-offs in other countries such as Sweden and the United States can also be attributed to university graduates (Åstebro et al., 2012).

501. In order to increase start-up activity at German universities, the topic of start-ups should be more firmly established in the **guiding principle** of knowledge and technology transfer (Kulicke and Berghäuser, 2017) but not at the expense of excellence in research. ↘ ITEMS 496 AND 591 Moreover, it appears that those interested in starting a company often lack business expertise. Training courses at universities and mentoring programmes offered by **incubators** (such as start-up centres as well as technology transfer offices at universities and major research institutes) can make a valuable contribution here (acatech, 2012).

↘ CHART 76
Innovation spending by large firms rising sharply; innovator share falling



1 – Data for 2019 based on planning figures from spring/summer 2019. 2 – Between five and 499 employees. 3 – 500 or more employees.
4 – Share of firms with product or process innovations as defined in the Oslo Manual (OECD and Eurostat, 2005). Break in the time series between 2005 and 2006 owing to changes in the group of respondents and the reclassification of economic activities from WZ 2003 to WZ 2008 and as a result of changes in the firm population owing to a switch from the Federal Statistical Office's specialised statistics and trade associations' statistics to the Federal Statistical Office's business register.

Sources: Mannheim Innovation Panel (MIP), ZEW

2. Innovation activity at firms

502. Private R&D accounts for more than two-thirds of total R&D spending in most developed economies. ↘ ITEM 493 Firms are mainly responsible for driving the development of market-ready products resulting from technological inventions. In recent decades, private spending on R&D in Germany has risen both in absolute terms and as a share of economic output. ↘ ITEM 493 At the same time, **innovation spending** has increasingly become **concentrated on large firms**. Innovation spending includes not just R&D spending but also other expenditure on the purchase of machinery, equipment, software and external expertise, if they contribute to the development, production or sale of innovations (Rammer et al., 2020a). Large firms with more than 500 employees have increased their innovation spending over the past 25 years much more sharply than small and medium-sized enterprises (SMEs) with fewer than 500 employees. In this chapter we have generally adopted the SME definition used by Eurostat, which defines SMEs as being firms with fewer than 250 employees and annual revenues of less than €50 million or total assets of less than €43 million. Where we have deviated from this definition, as in the case of ↘ CHART 76 LEFT, this is indicated accordingly. The share of German firms that have product or process innovations from the past three years (innovator share) has fallen steadily since the beginning of this century. ↘ CHART 76 RIGHT

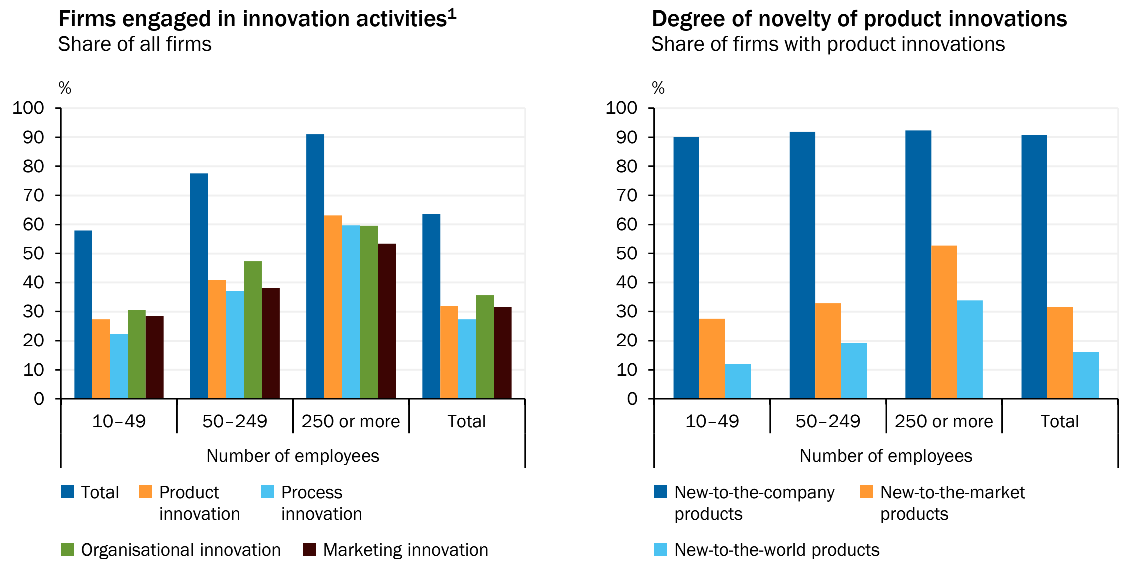
The role played by SMEs and large firms in the innovation process

503. **Large firms and SMEs** differ significantly in the ways in which they participate in innovation in terms of both the extent and **nature of their innovation activities**. This is clearly illustrated by their involvement in R&D. Whereas many SMEs do not engage in any R&D, the proportion of firms that do so rises in line with the size of firms. In Germany, for example, roughly two-thirds of all firms with more than 1,000 employees were continuously engaged in R&D during the period from 2016 to 2018 (Rammer et al., 2020a).

504. Large firms tend to have a stronger incentive than smaller firms to conduct **process innovation** because the cost savings from these innovations are greater for larger production volumes (Cohen and Klepper, 1996). This is especially the case with the digitalisation of many processes because these innovations incur high fixed costs and are easily scalable. ↘ ITEM 568 In addition, larger firms more frequently introduce organisational and marketing innovations as well as **product innovations.** ↘ CHART 77 LEFT Of all firms that launch product innovations, the proportion of large firms that introduce new-to-the-market or new-to-the-world innovations ↘ ITEM 509 is greater than it is for small firms. ↘ CHART 77 RIGHT Moreover, the proportion of revenue that large firms generate from new-to-the-market innovations is greater than it is for SMEs (Rammer et al., 2020a). Innovation at German SMEs is therefore driven less by their own product development than by the diffusion and adaptation of new technologies.

505. In the past, **large firms** were more heavily engaged in **basic research** than they are today. The amount of basic research conducted by US firms has declined since the early 1980s **in favour of applied research** (Arora et al., 2018). At the same

↘ CHART 77
Greater innovation involvement and higher degree of novelty at large companies in 2016



1 – Firms that engaged in innovation activities of the relevant type between 2014 and 2016, irrespective of whether these activities led to the market launch of new/improved products or the implementation of new/improved processes.

Source: Mannheim Innovation Panel (MIP) 2017, ZEW time, patent applications filed by firms increasingly relate to scientific publications (Marx and Fuegi, 2020). Such science-related patents are especially valuable and contain a high degree of novelty (Schnitzer and Watzinger, 2019). The proportion of patents based on publicly funded research is growing (Fleming et al., 2019), which might indicate the significant importance of public R&D investment.

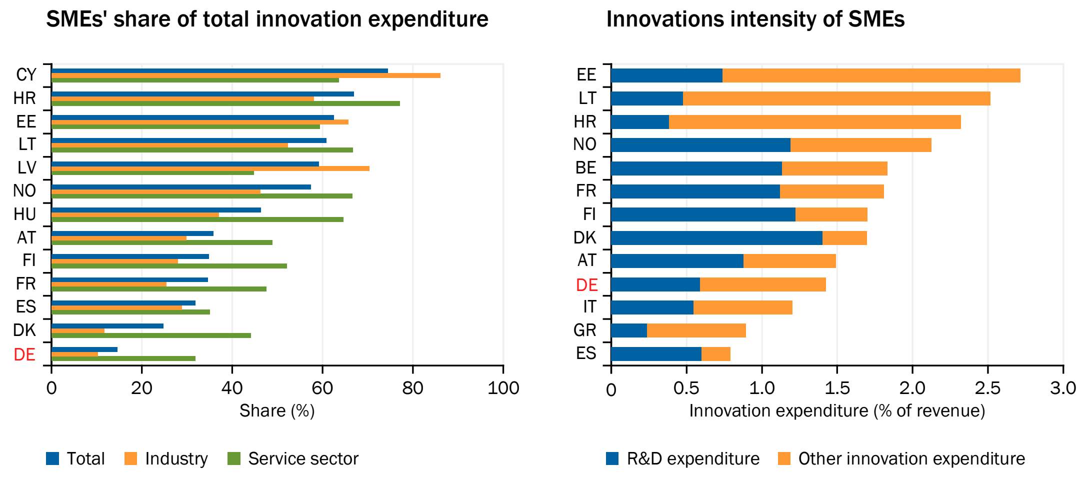
506. **Further innovation strategies** are available to larger firms in addition to their own internally conducted R&D. Knowledge can be acquired from innovative start-ups during the early stages by means of **corporate venture capital** and, subsequently, as a result of **takeovers.** ↘ ITEM 520 Start-ups funded by corporate venture capital in the United States tend to be more innovative than those financed by conventional venture capital (Chemmanur et al., 2014). An active market for corporate control can improve the exit options and, consequently, the incentives for smaller firms to invest in innovation (Phillips and Zhdanov, 2013). There is, however, a danger that large firms will acquire potential competitors in order to stop rival innovation projects (Cunningham et al., 2020).

German SMEs' innovation activities compared across Europe

507. Compared to other European countries, **the contribution of German SMEs to innovation activity** is modest relative to the contribution of larger firms. ↘ CHART 78 LEFT This applies equally to the manufacturing and the services sectors. The fact that large firms account for a high proportion of German R&D spending can be partly explained by their large share of value added. Even if the innovation intensity – i.e. the ratio of R&D spending to revenue – were the same for all sizes of firms, we would therefore expect R&D spending to be more strongly concentrated on larger firms. Secondly, however, the innovation intensity of German SMEs is lower than in many other European countries. ↘ CHART 78 RIGHT

↘ CHART 78

German SMEs[1] account for only a small share of innovation expenditure and have a low innovation intensity[2]



1 – Companies with between 10 to 249 employees. 2 – AT-Austria, BE-Belgium, CY-Cyprus, DE-Germany, DK-Denmark, EE-Estonia, ES-Spain, FI-Finland, FR-France, GR-Greece, HR-Croatia, HU-Hungary, IT-Italy, LT-Lithuania, LV-Latvia, NO-Norway.

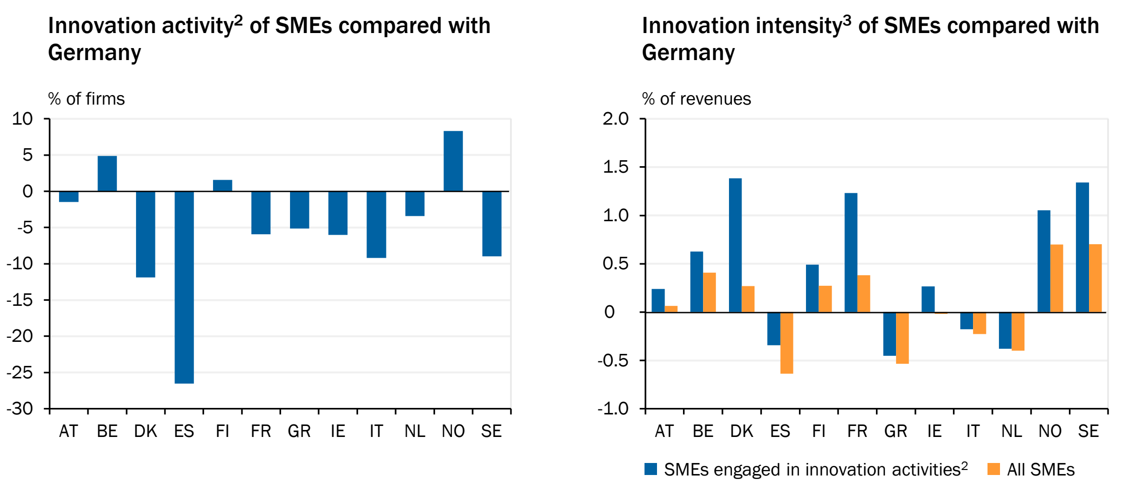
Sources: Eurostat Community Innovation Survey 2016, own calculations

The **Community Innovation Survey** (**CIS**) is a Europe-wide survey of innovation activity in the corporate sector that is conducted every two years on behalf of the EU by institutions in the member states. Firms are asked about their innovation activities over the preceding three years. Measures of innovation activity are based on the definition of innovation used in the Oslo Manual (OECD and Eurostat, 2019). The survey captures innovation activities such as product, process, marketing and organisational innovations as well as R&D activities and R&D spending. The survey also asks about innovations' degree of novelty as well as innovation strategies and the funding of innovations. It also identifies the innovation constraints hindering non-innovative firms. The survey data allow a comprehensive analysis of European firms' innovation activity broken down by country and sector.

508. One reason for the observed **low innovation intensity of SMEs** might relate to the **structure of the German economy**. It might be that a high proportion of the value added in Germany is generated by sectors in which SMEs have a low innovation intensity. In order to investigate this hypothesis, we use firm level data to correlate the innovation intensity of SMEs engaged in innovation activities, at the same time, with the country in which the firm is domiciled and with the sector in which the firm operates. Taking account of the sector hardly changes the correlation between the country in which the firm is domiciled and the firm's innovation intensity. ↘ CHART 97 APPENDIX LEFT

Even if we take account of sector-specific innovation intensity, SMEs engaged in innovation activities in Germany reveal a much lower innovation intensity than firms in most other European countries. One reason for this might be that, before tax incentives for R&D were introduced in 2020, Germany – unlike many other member states – did not have any indirect public support for R&D and, consequently, the total volume of public support was lower than in other member states

↘ CHART 79
German SMEs[1] are relatively often engaged in innovation activities but have a low innovation intensity



1 – Firms with fewer than 250 employees. AT-Austria, BE-Belgium, DK-Denmark, ES-Spain, FI-Finland, FR-France, GR-Greece, IE-Ireland, IT-Italy, NL-Netherlands, NO-Norway, SE-Sweden. 2 – A firm is said to be engaged in innovation activities if it has engaged in any product, process, marketing or organisational innovation activity in recent years. Value for Germany: 62.3 %. 3 – Innovation intensity indicates innovation spending as a percentage of revenues. Value for Germany: 1.9 %.

Sources: Eurostat Community Innovation Survey 2016, own calculations

(EFI, 2016). At the same time, however, the **proportion of German SMEs that engage in any form of innovation activity is much higher** than in other European countries. ↘ CHART 79 LEFT This conclusion is also **unaffected by the economic structure** of the country concerned. ↘ CHART 97 APPENDIX RIGHT The average innovation intensity of SMEs engaged in innovation activities in Germany is even further below that in other countries than the innovation intensity of all SMEs. ↘ CHART 79 RIGHT

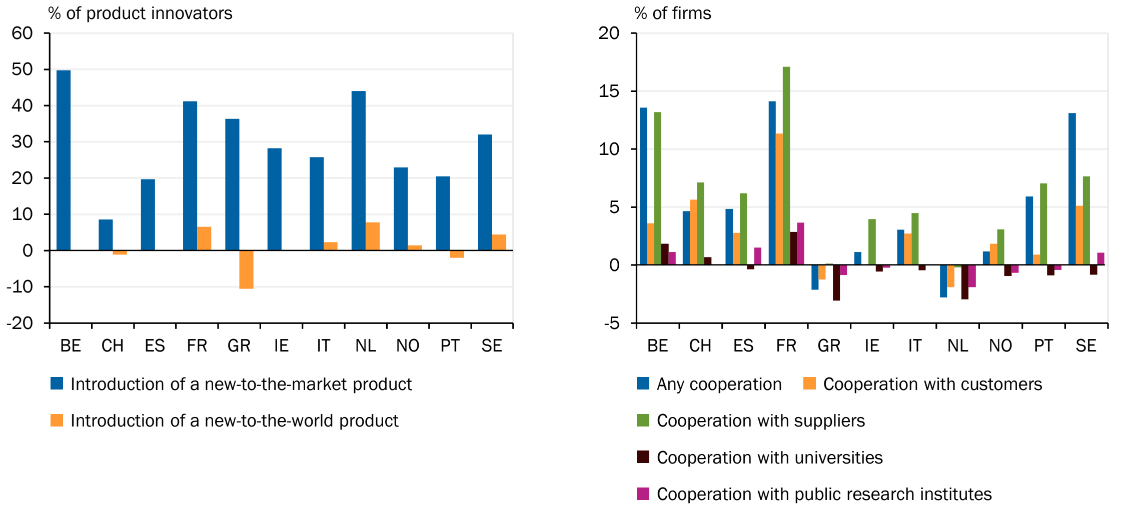
509. In addition to SMEs' research inputs and their involvement in innovation, the **quality of successful innovations** is a key performance indicator of their innovativeness. One measure of the quality of innovation in the context of product innovations is their **degree of novelty**. If we relate the degree of novelty to the specific market being served by SMEs, we can see that German SMEs introduce new-to-the-market innovations less frequently than SMEs from other European countries. ↘ CHART 80 LEFT It may be, however, that German SMEs operate in geographically larger markets containing more competitors. This might explain why – in relation to these markets – German SMEs introduce new-to-the-market innovations less frequently. If, alternatively, we relate the degree of novelty to the same market for all firms – the world market – then the comparison looks slightly more positive. Although, compared with other European countries, **German SMEs** that launch product innovations are also **less likely** to introduce a **new-to-the-world innovations**, the differences are much smaller than they are with the introduction of market innovations.

↘ CHART 80

German SMEs[1] introduce new-to-the-market products less frequently and cooperate less often with customers and suppliers

Degree of innovation novelty by SMEs compared with Germany[2]

Innovation cooperation by SMEs compared with Germany[3]



1 – Firms with fewer than 250 employees. BE-Belgium, CH-Switzerland, ES-Spain, FR-France, GR-Greece, IE-Ireland, IT-Italy, NL-Netherlands, NO-Norway, PT-Portugal, SE-Sweden. 2 – The percentages for Germany (baseline) are 29.2 % for the introduction of new-to-the-market products and 14.2 % for the introduction of new-to-the-world products. No data for Spain or Ireland are available for the introduction of new-to-the-world products. 3 – The percentages for Germany (baseline) are 8.5 % for any cooperation, 3.3 % for cooperation with customers, 3.0 % for cooperation with suppliers, 5.2 % for cooperation with universities and 2.5 % for cooperation with public research institutes.

Sources: Eurostat Community Innovation Survey 2016, own calculations

The CIS asks firms about the **degree of novelty of their product innovations.** Product innovations can be classified as new-to-the-firm, new-to-the-market, new-to-the-country, new-to-Europe or new-to-the-world products. Firms are asked what geographical market they operate in. A product innovation is described as being '**new to the market**' if it has not yet been offered by any other firm in this market of relevance to the firm. A **new-to-the-firm** product, on the other hand, must only be new to the firm surveyed, which means that it may already have been offered by other firms in this market. The terms '**new to the country**', '**new to Europe**' and '**new to the world**' denote whether a product has already been offered by another firm in the geographical market concerned – irrespective of the relevant market for the firm concerned.

510. One particular **innovation constraint for SMEs is the indivisibility of R&D projects** and the resultant minimum project sizes (Rammer et al., 2016). This means that SMEs can only carry out a few R&D projects simultaneously. In addition, the commitment of financial resources reduces the innovation activities that are necessary to successfully convert R&D results into marketable innovation. Moreover, SMEs – unlike larger firms – cannot diversify their risk by taking on a larger number of projects. And, last but not least, the R&D departments required for continuous R&D incur high fixed costs. This increases the average cost per project because of the lower number of R&D projects.

511. One way of overcoming these constraints is to enter into **research collaborations** either with other firms or with public institutions. Compared with SMEs in other European countries, German SMEs are neither especially likely nor especially unlikely to enter into collaborations. ↘ CHART 80 RIGHT The choice of collaboration partners reveals varying patterns in the countries analysed. German SMEs enter into fewer collaborations with customers and suppliers than SMEs in other countries. Collaborations with universities in Germany are more common than collaborations with customers or suppliers in comparison with other countries.

Human capital is essential for innovation at firms

512. A well-educated workforce is essential for firms' involvement and success in the field of innovation. Both measures are positively correlated with the proportion of employees who have a university degree. A lack of such qualifications can place a constraint on the introduction of new technologies and innovation projects (Acemoglu, 1998). A **shortage of skilled labour** has become an increasingly important **constraint on innovation activity** in Germany in recent years, especially for larger firms. Whereas in the mid-2000s only around 10 % of firms that were not engaged in innovation activities stated that they were not carrying out any innovation projects because of a lack of skilled labour, this proportion was recently 34 % (Rammer et al., 2020a). This factor was claimed to be a constraint on innovation especially in technology-intensive sectors such as electrical engineering, mechanical engineering and ICT. Analysis conducted by Germany's Federal Employment Agency (BA) for 2019 reveals shortages of skilled labour in technical professions and in ICT.

513. For a long time it was thought that a university education was the main driver of innovation (Aghion, 2008; Aghion et al., 2009, 2010). Recent studies have now shown that Germany's dual system of **vocational education and training** also has a positive impact on **innovation activity** (Backes-Gellner, 2017; Rupietta and Backes-Gellner, 2019; Horbach and Rammer, 2020). The introduction and diffusion of new techniques, technologies and processes is ensured by the **modernisation of curricula** so that general and firm-specific skills are taught that **enable trainees to engage with new innovative technologies** (Eggenberger et al., 2018). The task of modernising and developing vocational education and training in Germany falls within the remit of the Federal Institute for Vocational Education and Training (BIBB). This includes implementing the support programme initiated by the BMBF at the beginning of 2019 under the heading 'Shaping the future – innovations for excellent vocational education and training' (InnoVET). This programme is intended to encourage innovation clusters and to develop and test new educational and training offerings within these clusters.

The funding of innovation at firms

514. Larger established firms find it easier to finance innovation by drawing on reserves in the form of retained profits and can use regular revenues and collateral assets to secure bank loans. ↘ ITEM 492 Young and innovative firms, on the other hand, often have to resort to internal funds and external equity (Brown et al., 2009), such as in the form of venture capital. ↘ ITEM 520 **Government research funding can be used to overcome** the more serious **financing constraints facing young innovative firms**. Howell (2017) shows in the case of the United States that young firms that develop prototypes funded with government research grants are more likely to receive venture capital finance, file more patent applications and generate higher revenues. If government research funding enables patents to be developed, this can also mitigate future funding constraints if patents are used as collateral for loans (Mann, 2018).

515. In addition to direct research funding, **tax incentives for R&D spending** can also offer incentives for innovation activity. Indirect support for research through the tax system supplements direct funding and has the advantage of greater planning certainty for firms, lower administrative costs and its technology-neutral design (Harhoff et al., 2019). Empirical studies that use quasi-experimental designs (Bloom et al., 2002, 2019b) as well as panel studies (OECD, 2020a) suggest that tax incentives for R&D increase R&D inputs and outputs. This does, however, pose a risk of free-rider effects, for example the classification of expenditures as R&D spending when it is not actually R&D in the true sense (Chen et al., 2018; GCEE Annual Report 2018 item 604). The free-rider problem is, however, likely to be especially relevant in the case of larger firms (Falck et al., 2019a), which have more extensive tax avoidance options available.

516. **Germany introduced its first tax incentives for research in 2020 when it passed its Research Allowance Act** (German Act on Tax Incentives for Research and Development [FZulG]), thereby following many other OECD countries (OECD, 2020a). Firms' own research spending as well as contract research (up to 60 % of spending) can benefit from a subsidy of 25 % of the expenditure up to a

total eligible expense of €2 million. The limit of €2 million placed on eligible expenses benefits SMEs in particular. The specific inclusion of contract research takes account of the fact that many SMEs work with external partners. The government's economic stimulus package raised the maximum eligible expense to €4 million, which is mainly likely to benefit larger firms from the "Mittelstand" because most SMEs' R&D spending amounts to well below €2 million (Frietsch et al., 2019). ↘ ITEM 588

517. In addition to tax incentives for R&D, the **general tax regime** influences the innovation decisions taken by firms and researchers (Akcigit and Stantcheva, 2020). Akcigit et al. (2018) show in the case of the United States that higher income taxes and business taxes in a federal state reduce patenting activity and quality and cause researchers to move elsewhere. These effects are less pronounced if the research location is attractive for other reasons, for example if there is a concentration of other researchers in the same technology field. In addition, Curtis and Decker (2018) show that higher business taxes reduce the amount of start-up activity.

The fact that, under the usual tax regime, losses can only be offset against current and future profits reduces the appeal of risky projects, especially for young innovative firms that have not yet earned any profits. This affects their choice of innovation projects such that **less risky projects involving a smaller initial investment** and offering a high probability of success tend to be preferred over riskier projects offering a lower probability of success but higher financial returns if they are successful (Haufler et al., 2014). In addition, the preferential tax treatment of debt capital compared with equity (Feld et al., 2013) might hinder innovation activity given the considerable importance of equity in the funding of innovations.

3. Innovation activity of start-ups

518. **New firms** play an important part in economic growth, structural change (Dent et al., 2016) and productivity improvements (GCEE Annual Report 2019 item 183). However, only a small proportion of all new firms grow substantially and help to create jobs and achieve **macroeconomic growth** (Sedláček and Sterk, 2017; Pugsley et al., 2020). Many characteristics of the business founders and the firms that give a hint of subsequent growth are already evident at the time the business is started (Guzman and Stern, 2016, 2020). Young firms that are engaged in innovation in particular grow especially fast and contribute to macroeconomic growth (Stam and Wennberg, 2009; Helmers and Rogers, 2011; Egeln et al., 2012; Graham et al., 2018). It is therefore important to dismantle any obstacles preventing the foundation and growth of innovative firms.

519. **Firm creation activity** in Germany is **low** compared with other countries, and firm creation rates have been falling since the early 2000s (GCEE Annual Report 2019 items 184 ff.). However, it is unclear whether this can mainly be attributed to firms with low growth potential, or whether – as in the United States (Pugsley et al., 2020) – fewer high-growth firms are being founded. On the one

hand, survey data from the ZEW Start-up Panel suggest that the decline in the numbers of new firms has been accompanied by a decrease in the numbers of start-ups engaged in innovation (Berger et al., 2019). On the other hand, the KfW Entrepreneurship Monitor indicates that the number and proportion of digital growth-orientated firms with start-up characteristics has risen (Metzger, 2020a).

+

When considering the subject of firm creation, it is necessary to distinguish between **self-employment**, **setting up a new firm**, and a business **start-up**, although in casual speech these terms are often used synonymously. Self-employment describes the process of setting oneself up in business as a freelancer, which does not necessarily require a commercial enterprise to be registered. Setting up a new firm is characterised by the creation of a legally independent new commercial entity. Many firms that are set up are not growth orientated, create hardly any new jobs and are therefore not very relevant for the economy as a whole. A business start-up involves the formation of a new growth-orientated firm that has an innovative business model. Because there is no legal definition, start-ups are identified in administrative data based on the number of employees and revenue figures or their research orientation. Start-ups are identified in survey data by questions about their innovation and growth orientation (Metzger, 2020b).

520. Young growth firms – especially innovative ones – are often funded by **venture capital (VC)**. VC companies providing the funding are especially well placed to mitigate incentive and control problems (GCEE Annual Report 2019 items 132 ff.). Venture capital can make a valuable **contribution to the development and subsequent success of innovative growth firms** (Gompers and Lerner, 2001; Samila and Sorenson, 2011). In addition, the innovation activities of VC-funded firms generate substantial positive knowledge externalities for other firms' patenting activities. The knowledge externalities of venture capital investments are several times higher than the knowledge externalities of established firms' R&D investment (Schnitzer and Watzinger, 2020).

521. The **volume of venture capital available in Germany** to date is much lower than that of other developed economies (GCEE Annual Report 2019 items 285 ff.). After business conditions in the German VC market had steadily improved since the financial crisis, they fell to an all-time low in the wake of the **coronavirus crisis** (Metzger, 2020c). The government's economic stimulus package contained specific measures to support the venture capital market. The Corona Matching Facility of the KfW and the European Investment Fund provides private venture capital funds with public co-financing funds and makes additional funds available to start-ups through Germany's regional development banks. These measures are to be welcomed in the current situation. At the same time, the strong involvement of public investors in Germany compared with other countries underlines the fact (Metzger, 2020d) that private investment in the venture capital market needs to be strengthened.

522. Start-ups funded by **private venture capital tend** to perform **better** than those funded by **public venture capital** (Engel and Heger, 2005; Brander et al., 2010). These two forms of VC investment complement each other. Bertoni and Tykvová show (2012) in the case of Europe that financings led by private investors

and conducted jointly with public investors produce the highest levels of patenting activity. On the whole, public VC investment complements rather than substitutes private VC investment because it specialises mainly in niches that are of less interest to private investors (Bertoni et al., 2019). As part of early-stage funding, public VCs often invest in firms whose technologies and products take a particularly long time to launch in the market and require a considerable input of resources. As direct research funding does, public early-stage financing could help to overcome funding difficulties until prototypes are developed. ↘ ITEMS 514 FF.

523. **Venture capital from outside Europe** accounts for a considerable proportion of the European and German VC markets. Roughly 22 % of the firms in Germany funded by venture capital between 1992 and 2018 had at least one US investor (Woodward, 2019). Firms with foreign VC investors are more likely to be sold to a foreign firm or to realize an IPO on a foreign stock market (Braun et al., 2019). Findings from Sweden suggest that firms with US venture capital investment grow faster and create more domestic jobs than comparable firms without US venture capital backing (Hellmann et al., 2019).

III. DIGITALISATION PROVIDES POTENTIAL FOR PRODUCTIVITY GROWTH

524. General purpose technologies are characterised by their ability to be used in large sections of the economy and therefore have particular potential to increase productivity growth. Their broad scope of application leads to extensive positive externalities (Bresnahan and Trajtenberg, 1995; Jovanovic and Rousseau, 2005). There is likely still considerable growth potential, particularly in the area of **digitalisation** at present (i.e. digital rather than analogue information processing; development and use of ICT).

525. Various **technology trends** play a key role in digitalisation and form the basis for new business models. **Cloud computing** – the use of decentralised IT resources as a service – now enables on-demand use of ICT without incurring fixed costs. Large volumes of data (**big data**) from increasingly diverse sources are gaining importance as a production factor. Innovations in **artificial intelligence (AI)**, particularly **machine learning**, mean that computers are increasingly complementing and improving the performance of cognitive tasks previously only achievable by humans. Another key component of current technological change is the **connectivity of physical objects**, known as the **Fourth Industrial Revolution (4IR)**, and also as **Industry 4.0** in the context of industrial production. The German economy faces the challenge of addressing these developments, creating innovations and new business models, and implementing digital technologies to boost productivity and growth; and all steps of the innovation process are important.

1. Research, development and innovation

Innovation activity in the German ICT sector

526. The ICT sector, comprising both hardware manufacturers and ICT service providers, plays a central role in the process of digitalisation. It accounted for 3.7 % of gross value added in Germany in 2017. A significantly higher share of gross value added is generated by the ICT sector in South Korea (9.2 %), the United States (5.9 %) and Japan (5.7 %) (Mas et al., 2020). At 9 %, the proportion of **R&D spending by German companies in the ICT sector** is far below the share in South Korea (52 %) and the United States (30 %), and also **below the EU average** of around 15 %. The automotive industry has the largest share of German R&D expenditure, accounting for 37 % of spending on research and development. ↘ CHART 81 LEFT Although R&D expenditure in industries outside the ICT sector also goes to developing digital technologies, it is not possible to estimate the extent of spending on research and development on ICT in other industries due to a lack of respective data. In terms of **publicly funded ICT research**, Germany also only ranks around the **middle** on an international scale measured by the share of GDP. ↘ CHART 81 RIGHT

527. **Innovative activity** in the area of digitalisation can be determined in **different ways**. The **innovation rate** based on CIS data indicates the proportion of companies that have introduced at least one new product or process for the company in the past three years. The number of **patent applications** is a further indicator of the **outcome of the innovation process** (Pakes and Griliches, 1980). In addition to economic skills and computer-based information, patents form part of the **knowledge capital stock** (OECD 2013), and represent a major intangible production factor (Adarov and Stehrer, 2019).

528. The **innovation rate** of the German **ICT sector** was **59 % in 2018**, making it one of the most innovative sectors in Germany (Bertschek et al., 2020). Only vehicle construction and electrical/mechanical engineering have a higher rate of innovation. In the past, innovation activities in the German ICT sector were driven more by hardware manufacturers than by ICT service providers. As in the economy as a whole, the innovation rate in the ICT sector fell for five consecutive years until 2016, due primarily to the lower tendency to innovate among smaller ICT companies (Weber et al., 2018). ↘ ITEMS 503 FF. Only in 2017 did the innovation rate in the ICT sector start to rise again (Bertschek et al., 2020).

Germany's role in the Fourth Industrial Revolution

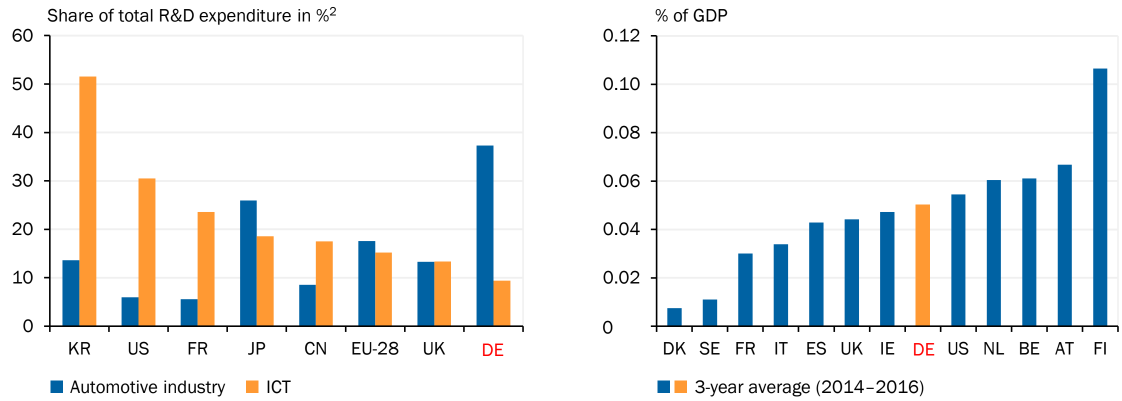
529. The European Patent Office (EPO) has classified patents for connected physical objects as a key digitalisation trend relating to the Fourth Industrial Revolution (Ménière et al., 2017). This enables assessment of **digital inventions at the current technological frontier**. An analysis of the 4IR patent applications from the period 1990 to 2016 shows the technological potential and level of specialisation in these key digital technologies in Germany and in an international comparison.

↘ CHART 81

International comparison of private R&D expenditure by sector and public ICT R&D fundings

Small share of German R&D expenditure in the ICT sector in 2017; large share in the automotive sector[1]

German ranks around the middle internationally for publicly-funded ICT research[3]



1 – Countries with highest R&D expenditure worldwide. KR-Republic of Korea, US-USA, FR-France, JP-Japan, CN-China, EU-28-European Union, UK-United Kingdom, DE-Germany. 2 – Share of R&D expenditure in firms of each industry of total of R&D expenditure of all firms. 3 – Publicly-funded R&D expenditure in information and communications technology in relation to GDP. DK-Denmark, SE-Sweden, FR-France, IT-Italy, ES-Spain, UK-United Kingdom, IE-Ireland, DE-Germany, US-USA, NL-Netherlands, BE-Belgium, AT-Austria, FI-Finland.

Sources: European Commission, OECD, own calculations

The advancing connectivity of physical objects equipped with sensors and processors and associated applications in recent years has come to be referred to as the **Fourth Industrial Revolution** (Schwab, 2017). The EPO differentiates between 16 technology fields, divided into three sectors. ↘ Table 18 Appendix Inventions classified as core technologies form the basis for 4IR applications, such as cloud storage and network protocols. The enabling technologies sector, such as 3D printing, machine learning and GPS-based position determination, comprises inventions in key technologies that can be used for the various applications. The third group of technology fields combines technologies from the other two sectors in application domains, such as autonomous driving, intelligent robotics, automated production and smart wearables.

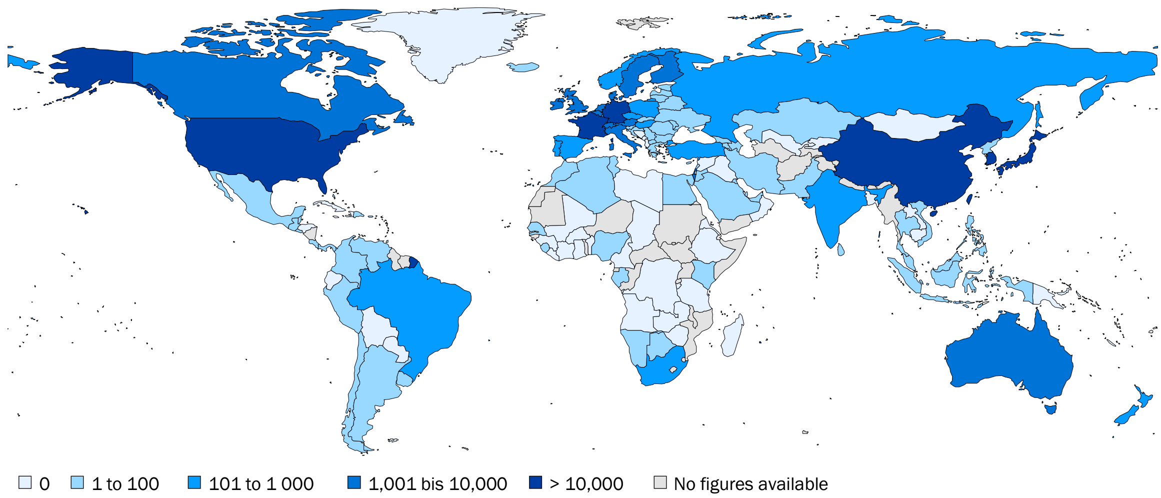
Behrens and Viete (2020) allocated all the patents in the EPO's worldwide patent statistical database PATSTAT from 1990 to 2016 in line with the EPO concordance table for the analyses presented here. The number of 4IR patent applications identified in PATSTAT has grown rapidly since the 1990s. The **significance of 4IR as an important technology trend** is evident in the increase in applications of associated inventions. The annual volume of applications for 4IR patents rose by an average of around 4 % between 2010 and 2016, while only increasing by around 1 % in other technology fields.

530. The majority of 4IR patents worldwide are held by applicants from the United States. ↘ CHART 82 Applicants from the United States hold around 30 % of 4IR patents, a similar share to that of the EU in total. **Germany is the leading 4IR patent applicant in the EU**, accounting for around 12 % of all worldwide applications, followed by France and the United Kingdom. In addition, many 4IR patents are held by applicants from Asia, particularly Japan, South Korea and, more recently, also China. The development of 4IR patent applications over time

↘ CHART 82

Number of 4IR patents[1] for the years 1990 – 2016

Highest number of 4IR patent application in Europe from Germany



1 – Fourth Industrial Revolution (4IR) patents are patents for connected physical objects.

Sources: EuroGeographics for the administrative boundaries, European Patent Office, own calculations

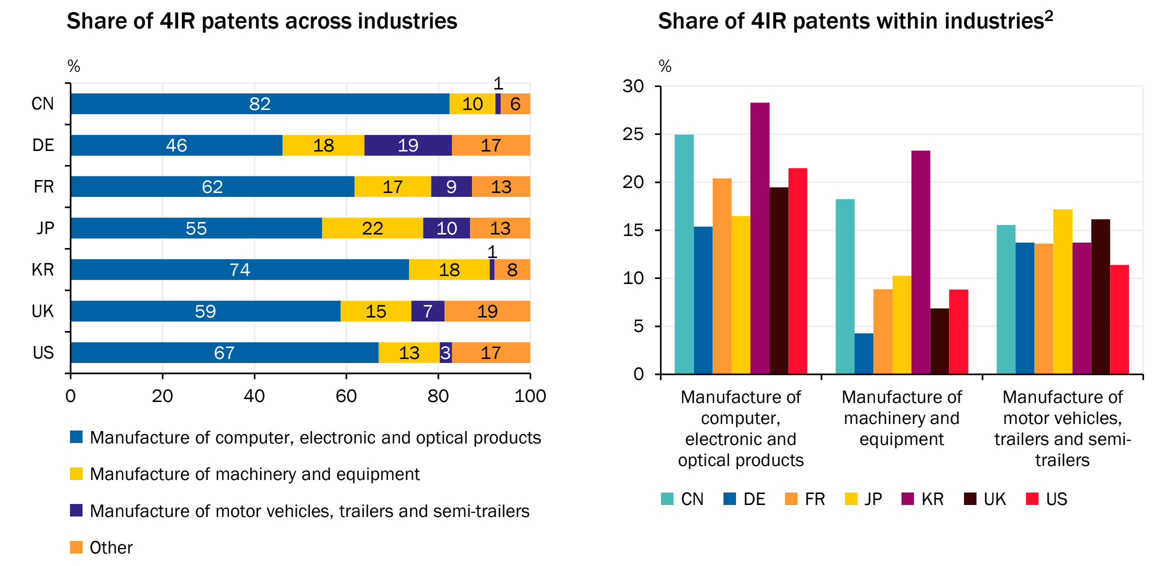
shows that their increase worldwide has been driven primarily by applicants from China and South Korea in recent years.

531. The **majority of 4IR patents are held by a small number of companies**. Around a quarter of the 4IR patents filed with the EPO between 2006 and 2016 are concentrated in 20 companies around the world. Particularly valuable and frequently cited patents are known as **breakthrough patents** (Squicciarini et al., 2013). There was a high regional concentration of breakthrough patent registrations between 1990 and 2011, with over 40 % from Japanese applicants, and almost 30 % from the United States. Germany accounts for just over 4 % of this type of patent, making it one of the leading holders of 4IR breakthrough patents in the EU, which holds a total of 15 % of these patents. South Korea held around 7 % of such patents during the period observed, and China less than 1 % (Behrens and Viete, 2020).

532. A **breakdown of applications by industry** and country shows that three industries are responsible for the majority of 4IR innovations in the major applicant countries. ↘ CHART 83 LEFT The most important industry sector as regards 4IR patent applications in many countries is **ICT hardware manufacturing**. In Germany, by contrast, ICT hardware manufacturers account for a comparatively small share of 4IR patent applications. This sector is more important for such applications in **China**, **South Korea** and the **United States**. The proportion of 4IR patent applications from the mechanical engineering sector in Germany is comparable to that of France and South Korea, but smaller than Japan. **Germany's automotive industry** accounts for a comparatively significant share of 4IR patent applications. The relatively large number of 4IR patents in the German automotive industry is primarily due the high general level of innovation activity in the sector. However, if we look at the share of 4IR patent applications within different sectors of the economy, ↘ CHART 83 RIGHT, we can see that the German automotive sector,

↘ CHART 83

High concentration of 4IR patents in few industrial sectors[1]



1 – Fourth Industrial Revolution (4IR) patents are patents for connected physical objects. Countries with the most 4IR patent applications. CN-China, DE-Germany, FR-France, JP-Japan, KR-Republic of Korea, UK-United Kingdom, US-USA. 2 – Industrial sectors with the most 4IR patent applications worldwide.

Sources: European Patent Office, own calculations

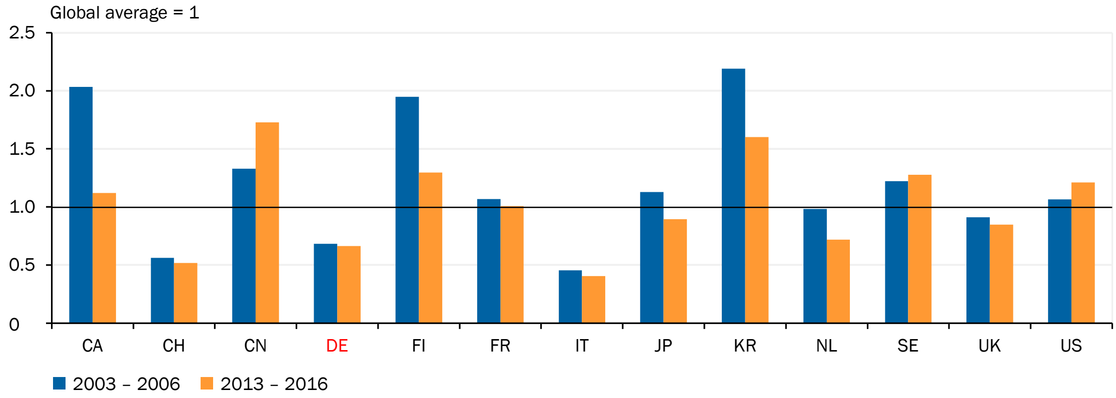
along with ICT hardware manufacturing and mechanical engineering, is not pushing 4IR innovation any harder than the equivalent sectors in other countries.

533. Germany has a comparatively high number of 4IR patents in absolute terms, ↘ CHART 82 but the German economy was consistently under-specialised in 4IR technologies from 2004 to the end of the observation period based on the **revealed technological advantage (RTA)** indicator. ↘ CHART 84 Although the 4IR is a major topic of public and political debate in Germany, the level of specialisation does not reflect the significance of these technologies overall. China, in particular, increased its relative specialisation in developing 4IR technologies between 2004 and 2016, as did Sweden and the United States.

The **level of technological specialisation** is measured by the **RTA** indicator, which compares the share of patent apllications in a particular technology field in a certain country with the total share of the same technology in patent applications worldwide (Dernis et al., 2019). An RTA index value of above 1 indicates a positive specialisation of the country in the respective technology field. A value of 1 shows that the country has the same share of patent applications in the technology area as the worldwide average, and a value below 1 indicates below average specialisation. The index is equal to zero when the country does not have any patents in the respective field.

534. Technological progress has been made very recently **in the area of AI** in particular, and new respective applications have been created. The Federal Government's AI strategy bundles measures to develop AI technologies in Germany, and is providing €5 billion in funding until 2025 (German Federal Government, 2018; Coalition Committee, 2020).

↘ CHART 84
Little specialisation in 4IR technologies for Germany in international comparison[1]
RTA index of patent applications[2]



1 – Fourth Industrial Revolution (4IR) patents are patents for connected physical objects. 2 – The RTA index (Revealed Technology Advantage index) is defined as the share of patents in a certain technoloy field in one country compared with the worldwide share of patents in the same field. Countries illustrated are those with the most 4IR patent applications filed between 1990 and 2016. CA-Canada, CH-Switzerland, CN-China, DE-Germany, FI-Finland, FR-France, IT-Italy, JP-Japan, KR-Republic of Korea, NL-Netherlands, SE-Sweden, UK-United Kingdom, US-USA.

Sources: European Patent Office, own calculations

The number of worldwide patent applications for AI technologies again shows the **significant position of the United States and Asian countries**, in particular Japan, China and South Korea. ↘ CHART 85 The share of AI patent applications in the EU is now falling behind. Germany was responsible for almost 6 % of the world's AI patent applications between 2005 and 2007, making it the EU leader. This share declined by almost half between 2015 and 2017, to just over 3 %. China in particular significantly increased its share of worldwide AI patents in the period from 2015 to 2017 as compared to 2005 to 2007, while the United States maintained its share (Baruffaldi et al., 2020).

Major value-added potential from digital business models

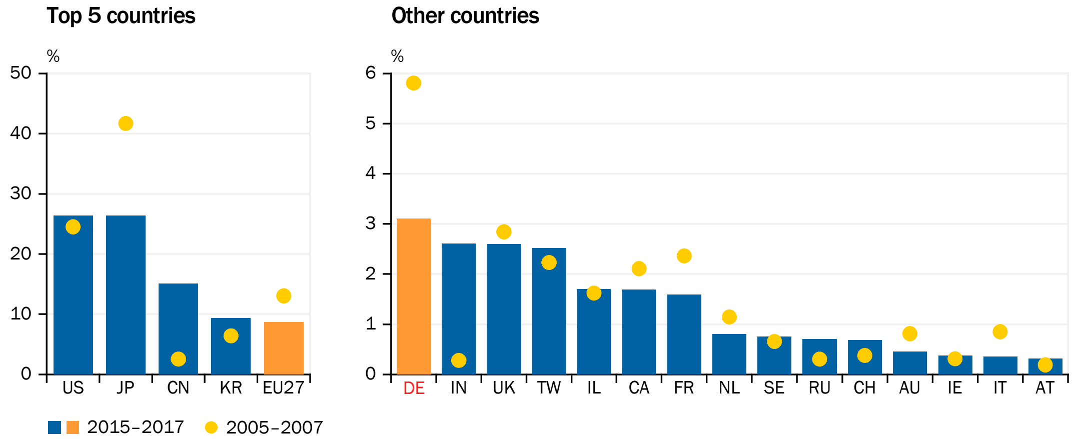
535. The dynamic development and **high value-added potential of data and platform-driven business models** are evident in the development of the **market capitalisation** of major companies in these sectors. A comparison of these companies with the most valuable DAX companies shows that US and Chinese platform-based business models dominate. ↘ CHART 86

These companies with disruptive business models increasingly appear as competitors from outside, or newcomers to the industry, such as Tesla in the automotive sector, and Google and Apple as FinTechs with e-payment options in the banking sector. Mergers and acquisitions are gaining in importance as a means of diversification for well-capitalized IT corporations (Bourreau and de Streel, 2020). ↘ ITEM 506 Since platform-based business models in particular benefit from rapid **scalability and network effects** between users (GCEE Annual Report 2019 item 311), European firms are at a competitive disadvantage because the **European domestic market** remains linguistically, legally and institutionally **fragmented**. It is therefore vital that the European single market, in particular the **digital single market**, be further deepened. ↘ ITEM 584

↘ CHART 85

Top 20 inventor countries for patents relating to artificial intelligence (AI)[1]

Share of AI-related patents worldwide



1 – The data refer to IP5 patent families in AI-related technologies, i.e. groups of patents for the same technological content at the five leading international patent offices. Data based on earliest filing date and inventor location. Data as of July 2020. US-USA, JP-Japan, CN-China, KR-Republic of Korea, EU27-European Union without Croatia, DE-Germany, IN-India, UK-United Kingdom, TW-Taiwan, IL-Israel, CA-Canada, FR-France, NL-Netherlands, SE-Sweden, RU-Russia, CH-Switzerland, AU-Australia, IE-Ireland, IT-Italy, AT-Austria .

Sources: OECD, own calculations

536. The **rapid development of the platform economy** has primarily been via services in **business-to-consumer (B2C) business models** thus far. However, digital business models in Industry 4.0 and 4IR technologies, which are extremely relevant for Germany due to the importance of the manufacturing industry, are now largely developing in **business-to-business (B2B)** markets. B2B platforms for goods and services, data and Industry 4.0 applications are at a comparably early stage of development (Saam et al., 2016; Koenen and Falck, 2020).

Increasing importance of data for innovations

537. **Data** is gaining **significance in the innovation process**, representing an increasingly important production factor as digital transformation progresses (Niebel et al., 2019). Digitalisation of information expands the stock of potentially available external knowledge as a quasi-public good, and can thus promote positive knowledge externalities (Antonelli, 2017). Moreover, new technologies such as big data and AI are cutting the costs of identifying and processing information, and facilitating the integration of external knowledge at firm level (Cohen and Levinthal, 1989). Public and free **availability and usability of data** is therefore of central importance.

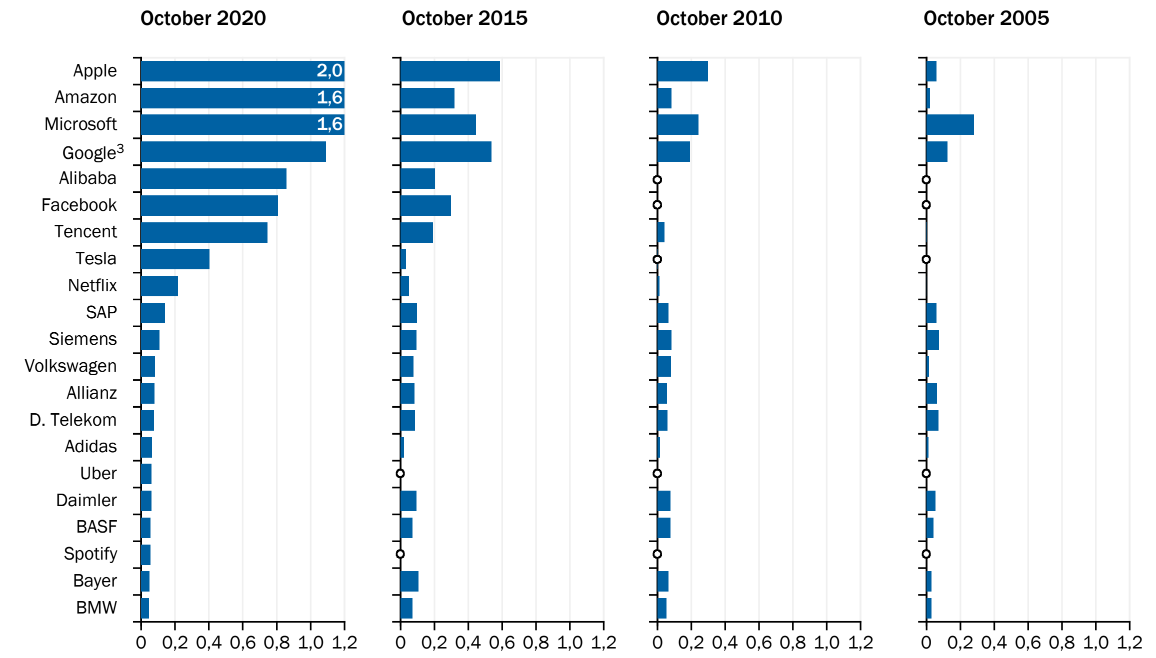
538. There are still major **bureaucratic hurdles** in scientific research in Germany as regards the **use of individual and company data** (Braun, 2020). The public sector is hesitant to provide data for private business models. The availability of public data is rather mixed at federal state level, and less than 1 % of German cities and municipalities actively make public data accessible (Schweigel et al., 2020).

There is also a lack of **standardisation in data structures and formats** across public-sector entities. This is a fundamental requirement for commercial

↘ CHART 86

German Dax companies[1] lag far behind market capitalisation of large digital companies

US-$ billion (nominal)[2]



1 – The 10 most valuable DAX companies at year-end 2019. Source: Capital. 2 – Sign o denotes no value available as the company didn't exist or had not yet been traded on the stock exchange. 3 – New name Alphabet from October 2015 after restructuring.

Sources: Capital, Refinitiv Eikon

use of public data (Commission of Experts on Competition Law 4.0, 2019). Examples of innovative business models based on freely-available administrative data can be found, among other places, in the United Kingdom, where combined public and private data is used in retail for location planning solutions (Bitkom, 2017). In Germany, mobility solutions are created in the private sector using regional public data; these solutions include offers for on-demand bus services to close gaps in local public transportation networks, and information on utilisation of car parks. Data from the US Centers for Disease Control and Prevention (CDC) was used to develop personalised treatment plans for asthmatics based on local environmental triggers (EFI, 2016). Overall, however, it is evident that the potential offered by available **open public data** for scientific and business innovations has barely been used to date, due to a lack of accessible data offerings (Schweigel et al., 2020).

539. One of the main challenges facing companies is creating functioning **business models** from new digital technologies. In this context, (product support) data-based **services** and associated closer, long-term **customer relationships** are gaining importance (Weill and Woerner, 2013; OECD, 2015). Product support services provide an insight into user behaviour and can also result in positive **feedback loops** for ongoing sales and product innovation. At individual level, this can however also create **lock-in effects** (Commission of Experts on Competition law 4.0, 2019). Moreover, technological developments require the continuous adaptation of IT systems to **threat scenarios**, for example through software

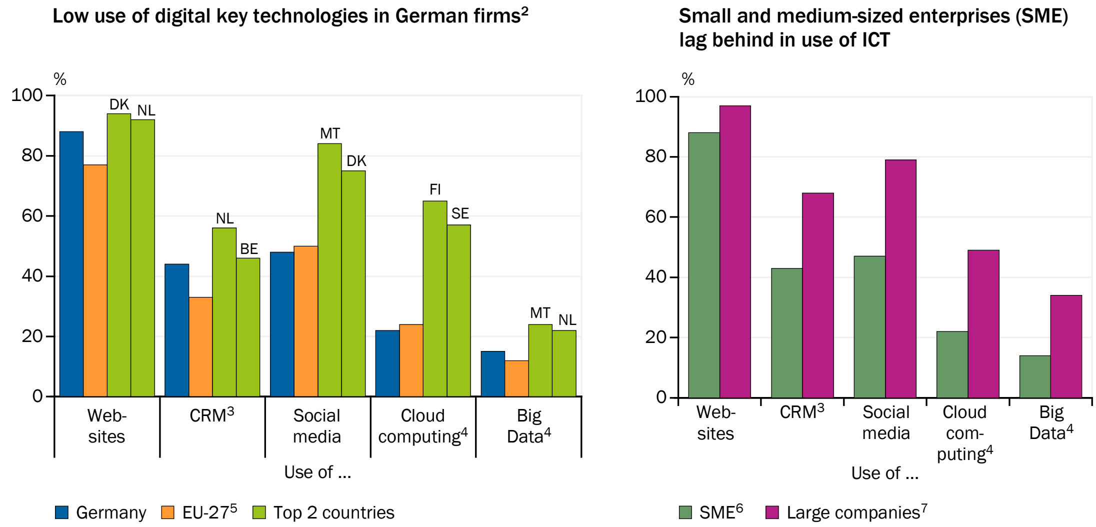
updates (Association of Technical Inspection Agencies (VdTÜV) 2019; Cyber Security Cluster Bonn, 2020). Digital business models are often based on new revenue models, such as licence models and subscriptions (OECD, 2014). The framework created by policymakers now has to increasingly address the fact that **data are a key production factor**.

2. Diffusion of digital technologies in companies

540. In order to leverage their value-added potential, the diffusion of digital technologies in companies, public sector institutions and households is vital. The **usage rates of various technologies** provide information on the status of the digital transformation in **companies**. ↘ CHART 87 LEFT For example, German companies are shown to have high usage rates compared with other European countries, particularly of IT solutions that have been prevalent for some time, such as operating their own website or using customer relationship management (CRM) software. However, they are lagging behind when it comes to more recent key technologies that enable data-driven value creation, such as social media applications, cloud computing and big data.

541. **Digital technologies** are primarily used by **large companies**. SMEs have thus far introduced such technologies at a later stage (OECD, 2019a) and overall less frequently. ↘ CHART 87 RIGHT Looking at SMEs in the German "Mittelstand" with an annual turnover of up to €500 million, the share with completed digitalisation projects has risen continuously since 2014. However, digitalisation has only been gradual in the German SME sector. It is rare to see disruptive use of ICT entailing

↘ CHART 87
Use of digital key technologies in German firms in 2019
Share of firms[1]



1 – Companies with at least 10 employees. 2 – DK-Denmark, NL-Netherlands, BE-Belgium, MT-Malta, FI-Finland, SE-Sweden. 3 – Customer relationship management. 4 – Data as of 2018. 5 – European Union without United Kingdom. 6 – Companies with 10 to 249 employees. 7 – Companies with 250 or more employees.

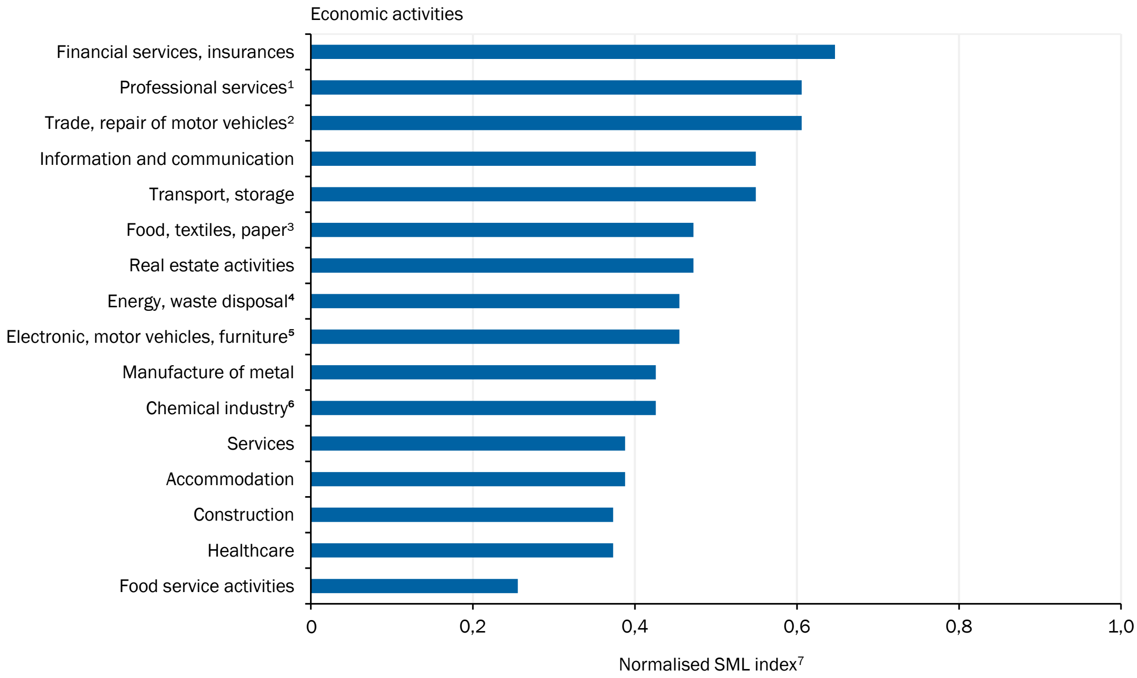
Source: Eurostat

a fundamental change in the business model (Zimmermann, V., 2020). A frequently discussed concern is that these differences in the diffusion process will lead to a **growing divide** between highly digitalised, often larger **frontier firms** and a large number of less digitalised smaller **laggards** (Bajgar et al., 2019a; Zimmermann, V., 2020). As the use of new technologies requires reorganisation of business processes, younger companies are at an advantage due to lower adaptation costs, and are more ICT intensive. This is evident not least in a more pronounced business dynamism in digital-intensive sectors (Calvino and Criscuolo, 2019).

542. The level of automation is constantly on the rise parallel to the digital transformation of production. **Automation of production processes** has further increased around the world in recent years through the use of robots. An average of 346 industrial robots per 10,000 employees were in use in Germany's manufacturing sector in 2019, with the largest number in the automotive industry. This puts Germany in fourth place in the global ranking of the most automated nations in 2019, behind Japan, South Korea and Singapore (IFR, 2020).

↘ CHART 88

Financial service sector most exposed to machine learning



1 – Professional, scientific and technical activities. 2 – Wholesale and retail trade, repair of motor vehicles and motorcycles. 3 – Manufacture of food products; beverages and tobacco products; wearing apperal; leather and related products; wood, paper, printing and reproduction. 4 – Energy and water supply; water and waste disposal; remediation activities. 5 – Manufacture of computer, electronic and optical products; electrical equipment; machinery and equipment; motor vehicles, trailers and semi-trailers; other transport equipment; furniture; other manufacturing; repair and installation of machinery and equipment. 6 – Manufacture of coke and refined petroleum products; chemicals and chemical products; basic pharmaceutical products and pharmaceutical preparations; rubber and plastic products; other non-metallic mineral products. 7 – Suitability for Machine Learning (SML) index. Normalised with highest and lowest SML score (Brynjolfsson et al., 2018) by occupation and defined between 0 and 1.

Sources: BA, BLS, Brynjolfsson et al. (2018), own calculations

Germany's use and development of **service robotics** was less pronounced in the past than its patenting activitiesand usage of industrial robots. Countries such as Japan and South Korea were far ahead in this area (EFI, 2016). Service robotics is considered to have great growth potential, and is used both commercially and for personal services. The significant areas of application in terms of worldwide sales figures are commercial service robots in logistics, medicine, agriculture and defence. Personal service robotics are primarily used for domestic chores, leisure and entertainment, and to a lesser extent for security and care (EFI, 2016; IFR, 2019).

543. Around 5.8 % of companies in Germany used **AI applications** in 2019. This share was highest in the ICT sector at around 17.8 %, as it is a developer and user of AI (Rammer et al., 2020b). Past studies have assumed that use of AI in the future will involve reorganisation of production processes and cause positive productivity effects (Aghion et al., 2019; Brynjolfsson et al., 2020b; GCEE Annual Report 2018 items 132 ff.). ↘ ITEM 565

544. The AI branch currently most used in German companies is **machine learning** (Rammer et al., 2020b). The future application potential of machine learning can be estimated based on the tasks performed by a firm's employees. Similar to the approach in the literature on automation (Arntz et al., 2017; Frey and Osborne, 2017), the application potential is measured at the occupational level by the suitablility for machine learning of the tasks performed within the occupation (Brynjolfsson and Mitchell, 2017). The occupational measures are weighted by number of employees and projected onto the German business landscape. This shows high application potential for machine learning in Germany's financial services and insurance, as well asretail, wholesale and automotive trade sectors. ↘ CHART 88 The application potential is lower in service sectors with a large number of workers performing customer or people-related tasks and physical work, such as food services, construction and healthcare.

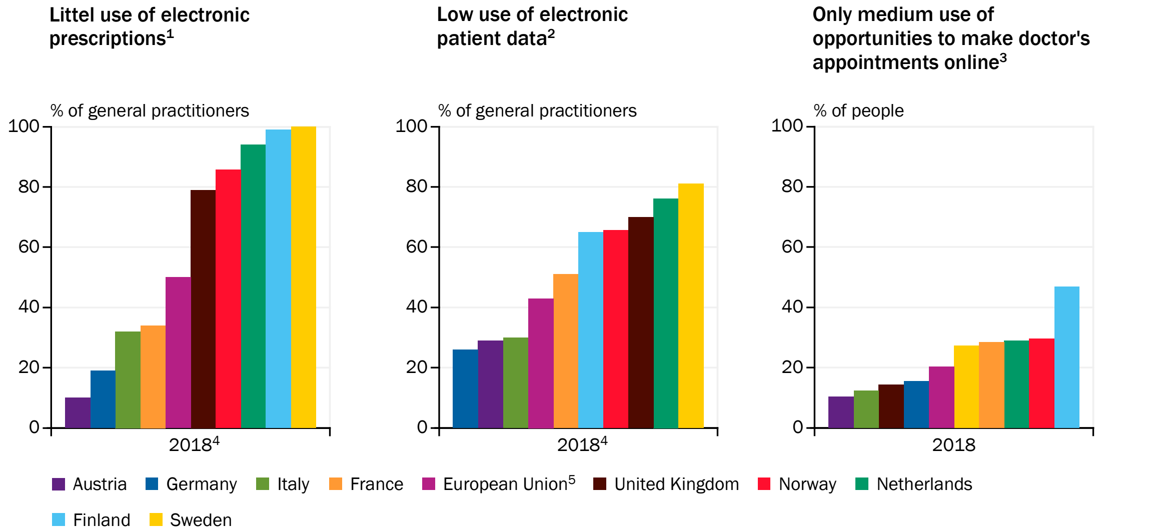
3. Coronavirus crisis boosts digitalisation

545. Contrary to the general observation that the introduction of technologies is generally pro-cyclical, ↘ ITEM 490 the **coronavirus pandemic** is expected to promote the **development** of and **transition** to **new digital technologies**. This will firstly be fuelled by stricter hygiene rules in the medium term, which will lead to higher costs in non-automated and non-digitalised firms. Secondly, many firms have gained experience with digital working methods during the pandemic and adapted their work organisation to these technologies, which will likely reduce the costs of transition and learning given a permanent transition. In addition, the COVID-19 pandemic has brought the status of digitalisation in the systemically important areas of healthcare, education and public administration into focus.

Digitalisation of the healthcare sector

546. **Digitalisation in the German healthcare and medical technology sector is progressing further**, for instance via the use of AI, new developments in

↘ CHART 89
German use of eHealth in European comparison



1 – Percentage of general practitioners that use electronic networks to transmit prescriptions to pharmacies. 2 – Percentage of general practitioners that use electronic networks to exchange patients' medical data with other healthcare professionals and specialists. 3 – Percentage of people aged 16 to 74 who have used the internet to book a doctor's appointment via a website in the past 3 months. 4 – Data for the Netherlands and Norway only available from 2013. 5 – Including United Kingdom.

Source: European Commission

sensor technology and individualised medical technology (GCEE Annual report 2018 items 894 ff.). The Digital Healthcare Act (Digitale-Versorgung-Gesetz, DVG) and the adoption of the Future of Hospitals Act (Krankenhauszukunftsgesetz, KHZG) during the COVID-19 pandemic are intended to accelerate digitalisation in the healthcare sector. This primarily includes expanding the digital network in the healthcare system, particularly in hospitals, promoting the prescription of paid healthcare apps certified as medical devices, electronic medical certificates and e-prescriptions, and increased information transparency via online consultations. The investments in digital infrastructure in hospitals provided for in the KHZG are particularly welcome. A shift to paperless electronic prescriptions will enable a quicker contactless transfer of information, as is already common practice in the neighbouring Netherlands. ↘ CHART 89 LEFT A transition from paper to digital at municipal health authorities could make communication channels faster and less prone to error with a view to tracking chains of infection and ordering tests and quarantine. This transition is set out in the Pact for the Public Health Service of 29 September 2020. ↘ ITEM 186

547. Challenges in creating digital offerings in healthcare were particularly evident in the development of Germany's **COVID-19 contact tracing app** (Corona-Warn-App), as the public's concerns about **data security and privacy** continue to hamper the take-up of the app in Germany (Bitkom, 2020a). The concerns surrounding data privacy were at the centre of a major controversy regarding the choice of a centralised or decentralised approach to data processing in connection with the development of the app (Dachwitz, 2020). At the same time, the **dependency on major US technology companies** has become clear (Rosemain and Busvine, 2020). For instance, Google and Apple, which together dominate the market for mobile device operating systems, managed to establish decentralised

data storage as a de facto universal standard by creating a uniform programming interface for contact tracing. In addition, the high demands on data protection, which were addressed when developing the app, limited possibilities for the authorities to track the spread of infection. And finally, there was initially a **lack of coordination** in the **development** of the contact tracing app **in the EU**, resulting in differing national approaches and impeding cross-border interoperability (Abboud et al., 2020).

548. **Digital diagnoses** by telephone or video consultations (telemedicine) **enable** patients to consult doctors without having to be physically present, thereby **potentially increasing efficiency**. Bavafa et al. (2018) demonstrate that the introduction of telemedicine in the United States in 2012 did not lead to a reduction in visits to the doctor, but actually to an increase of around 6 %. However, this study did not include the effect on the state of health. In the coronavirus pandemic, telemedicine would have the advantage of enabling an **initial digital diagnosis**, thereby reducing the contact risk and slowing the spread of the pandemic.

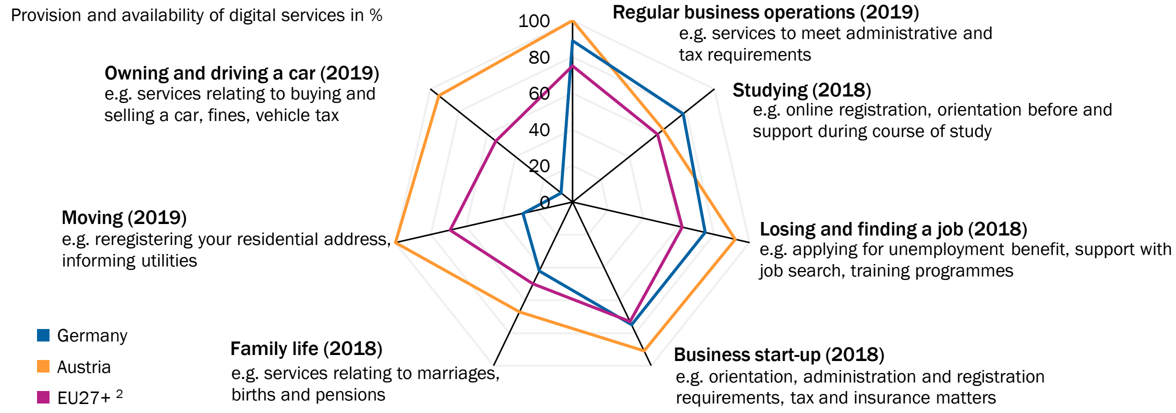
549. In a **European comparison** of **e-health**, i.e. the use of ICT in the healthcare sector, in 28 countries, **Germany ranked 26th** in e-health services in 2017, and in 2018, **17th** in medical data exchange, **and 22nd** in e-prescriptions (European Commission, 2019a). ↘ CHART 89 The Act on Medical Appointments and Healthcare (Terminservice- und Versorgungsgesetz, TSVG) will introduce the electronic patient file (ePA) with effect from 2021, which patients subject to statutory health insurance will receive from their insurers, and which can be viewed via an app. ↘ CHART 89 CENTRE The ePA will serve to transmit critical medical information directly in the health and long-term care sectors, which could lead to an increase in efficiency and productivity by reducing the time and effort required to obtain information (Hitt and Tambe, 2016). While Germany was above the EU average as regards seeking online information about health in 2019, at around 66.5 % (EU average: 54.9 %) (European Commission, 2020a), Germans do not generally make doctors' appointments online, similarly to their European neighbours. ↘ CHART 89 RIGHT There remains unexploited potential for increasing efficiency (Widhalm et al., 2015).

550. The **healthcare system** is experiencing a vital **digitalisation boost** due to the **coronavirus pandemic**. While it has clearly been lagging for quite some time (GCEE Annual Report 2018 items 894 ff.), the pandemic has increased the urgency of progressing with digitalisation. According to survey data from the Mannheim Institute of Public Health (Obermann et al., 2020), the availability of video consultations from doctors' surgeries in areas necessitating a high level of communication increased significantly in 2020. Of the doctors using video consultations when surveyed, 94.1 % stated that they had only introduced them in 2020. Medical practices in the area of psychology/psychiatry in particular currently use video consultations, with around 80.5 % offering them, whereas they are only used by between 25 % and 35 % of specialists and general practitioners.

↘ CHART 90

Full digitalisation of central services for citizens by life event[1]

Room for improvement in provision of digital public services in Germany



1 – The requirements of full digitalisation are met when i.e. a transaction can be executed without changing the information-carrying medium. The indicator includes the following four key elements of online service provision and availability: electronic identification (government-issued document for online identification and authentication), electronic documents (documents that have been authenticated by recognised means under applicable national law, in particular by use of electronic signatures), authentic sources (base registries used by governments to automaticall validate or fetch data related to individuals or businesses) and digital post (possibility for governments to communicate by electronic means only with people or entrepreneurs, such as through personal mailboxes). 2 – EU 27 plus United Kingdom, Iceland, Norway, Montenegro, Serbia, Switzerland, Turkey, Albania and North Macedonia.

Source: European Commission

Digitalisation of public administration

551. **Germany presently ranks 21st** out of 28 countries in the EU in the area of digital administration (**e-government**) according to the e-government index, which is based on five indicators showing the availability and use of digital public services (European Commission, 2020b). In terms of the services offered to companies, public administration shows slightly above-average online availability, while important services for the general public are not offered fully digitally for all life events. ↘ CHART 90 The availability and provision of digital services in four of the seven events covered is above the average of the EU 27+ and meets the full digitalisation requirement, while three events are below the average. The services not fully available digitally include registering and deregistering a car, registering a new residential address and marriage services. As regards the services already offered digitally, we can see that fewer residents in Germany use online forms (24.7 %) than the EU average (43.7 %) (European Commission, 2020c). The pandemic could lead to an increase in the digital use of public services.

552. The slow expansion of the e-government services could be due to a lack of investment funds, strict security requirements, a lack of coordination between federal, state and municipal governments in developing the application of information technology, and a lack of willingness to innovate by the administrative authorities. Increased **digitalisation of administration** could lead to **increased productivity in the public sector**, for instance by improving the exchange of information through digital networking of the administrative authorities (Beck et al., 2017). In addition, digital interfaces can increase incentives for companies to digitalise, such as through requirements to use Building Information Modelling (BIM) in public tenders for construction.

553. The aim of the Online Access Act (Onlinezugangsgesetz, OZG) of 2017 is to **advance the digitalisation of administration**. It requires federal, state and municipal governments to offer administrative services digitally via administrative portals by the end of 2022 (NKR, 2020). The Federal Government's National Regulatory Control Council (NKR) points out that although investment decisions will be eased by the OZG through the coronavirus stimulus package of some €3 billion and a further €300 million for the purpose of register modernisation, the resources are insufficient to accelerate digitalisation. Possible solutions include in particular reducing the complexity of the implementation of the OZG and accelerating the implementation scenarios by standardising and simplifying technical and procurement procedures. The coronavirus crisis has made it clear that there is a lot of catching up to do in the area of digital administration, so it is all the more important to use the crisis as an opportunity to catch up here. The stimulus package could help in this regard.

Digitalising the education system

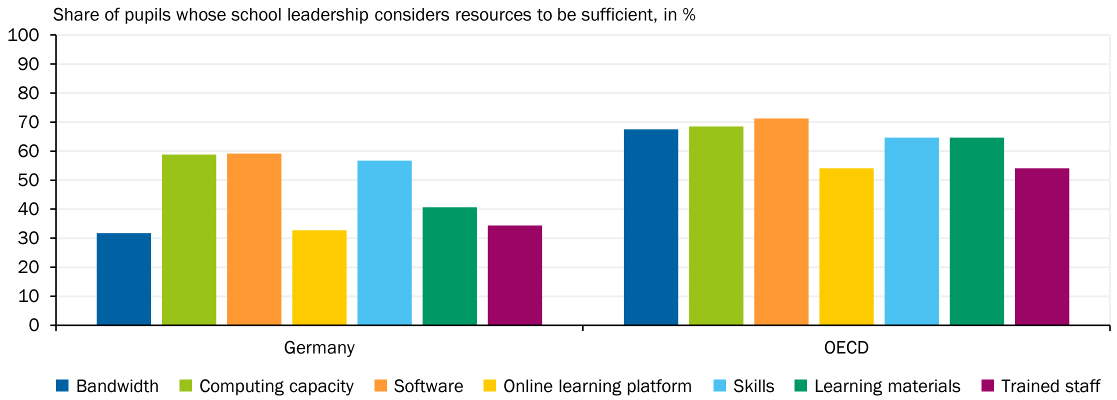
554. Schools in Germany were closed three weeks longer during the COVID-19 pandemic than the average of the OECD countries, while the transition to digitally-supported learning proved more difficult than in other countries (OECD, 2020b). A **boost to digitalisation in the education system would help** to continue instruction in the event that the infection rate rises again (Leopoldina, 2020; OECD, 2020c), and at a minimum, the use of digital offerings must be ensured in the short term.

Irrespective of the current pandemic, digital teaching and learning opportunities and the **digital infrastructure in schools must be expanded** to equip future generations with key digital skills, both as users and as employees and future developers (EFI, 2016).

↘ CHART 91

Quality of material and human ICT resources in everyday school life in 2018[1]

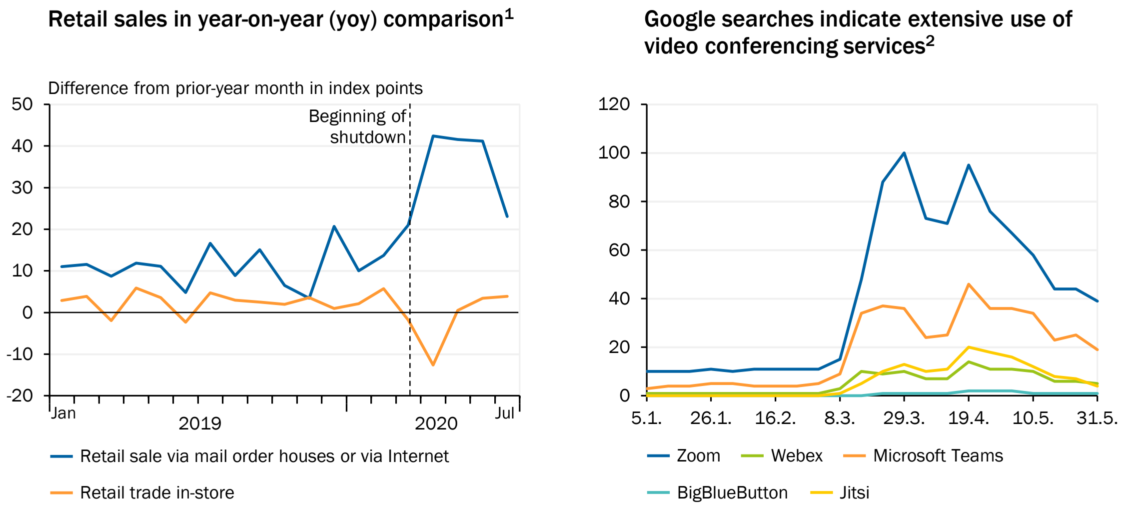
Quality of material ICT resources in Germany is below OECD average



1 – Bandwidth: the school's internet bandwidth or speed is sufficient; computing capacity: digital devices at the school are sufficiently powerful in terms of computing capacity; software: the availability of adequate software is sufficient; online platform: an effective online learning support platform is available; skills: teachers have the necessary technical and pedagogical skills to integrate digital devices in instruction; learning materials: effective professional resources for teachers to learn how to use digital devices are available; trained staff: the school has sufficient qualified technical assistant staff.

Source: Reiss et al. (2019)

↘ CHART 92
Retail sales and Google searches in Germany



1 – Difference in sales from prior-year month (2015 = 100). 2 – Google searches on terms Zoom, Webex, Microsoft Teams, BigBlueButton and Jitsi. Data as of 8 June 2020. Search interest relative to highest point on chart. 100 represents maximum popularity of the search term.

Sources: Federal Statistical Office, Google Trends, own calculations

555. An analysis of the **use of ICT in German schools** based on data from the 2018 PISA study shows that the schools are so far lagging behind. For example, the proportion of pupils whose school leaders consider the quality of material and human ICT resources to be sufficient is **below the OECD average** (Reiss et al., 2019). ↘ CHART 91 The main weak points are the school's bandwidth and speed of internet connections, the availability of learning platforms, and access to trained technical staff. Differences between countries as regards information on the quality of the ICT infrastructure could be due to differing expectations of the school leaders surveyed. However, quantitative indicators such as the number of computers per pupil reveal that Germany (0.6) is below the OECD average (0.8), and far behind countries such as the United States (1.5) and Sweden (1.1) (OECD, 2020d).

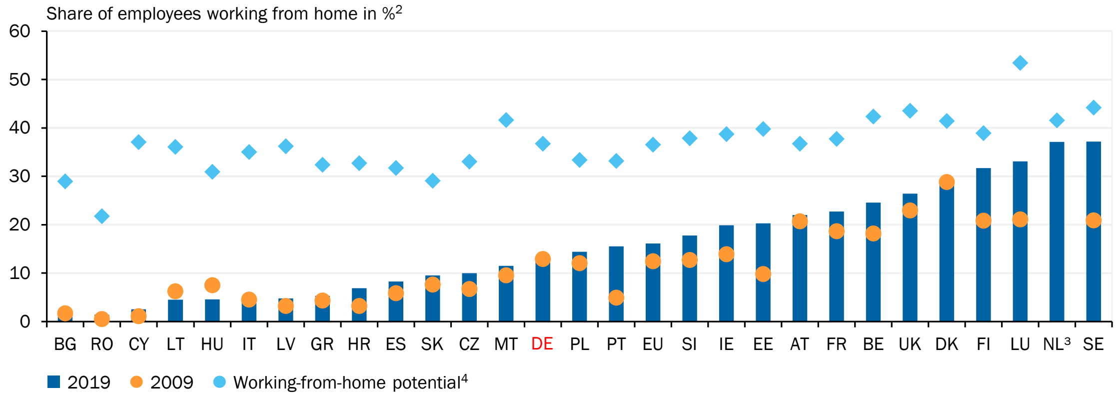
556. The **Digital Pact for Schools** (DigitalPakt Schule) introduced by the Federal Government in 2019 is intended to support and promote the development of digital learning infrastructures in German schools, with €5 billion in funding provided at the federal level, and an additional €555 million by the states. However, roughly a year later, only €242 million, or around 5 % of the €5 billion, had been approved in 14 federal states (Federal Government, 2020). One obstacle to the take-up of funds is the necessary preparation of a media concept; others being the lack of human resource support in creating and maintaining the digital infrastructure, and lack of access for teachers to learning materials on the use of digital equipment. In addition, the digital infrastructure is inadequate at times due to low or unavailable bandwidth and speed. ↘ CHART 91

Digitalisation of retail and mobile working

557. **Mail order and online shopping** in Germany increased in particular as a result of the short-term closure of retail stores in April 2020, while in-store retail

↘ CHART 93

Low rate of working from home in Germany before pandemic in European comparison[1]



1 – BG-Bulgaria, RO-Romania, CY-Cyprus, LT-Lithuania, HU-Hungary, IT-Italy, LV-Latvia, GR-Greece, HR-Croatia, ES-Spain, SK-Slovakia, CZ-Czech Republic, MT-Malta, DE-Germany, PL-Poland, PT-Portugal, EU-European Union, SI-Slovenia, IE-Ireland, EE-Estonia, AT-Austria, FR-France, BE-Belgium, UK-United Kingdom, DK-Denmark, FI-Finland, LU-Luxembourg, NL-Netherlands, SE-Sweden. 2 – Share of employees working sometimes or usually from home. 3 – No data available for 2009. 4 – Share of employees that could do their job completely from home.

Sources: Dingel and Neiman (2020), European Labour Force Survey (EU-LFS), own calculations

declined. ↘ CHART 92 LEFT This development reinforces the structural change already underway in retail, from physical to online sales (Jonas, 2019).

558. Germany has thus far been towards the bottom of international rankings when it comes to **cashless payments**. A total of 75.7 cashless payments were made per person in Germany in 2019, whereas Denmark saw around five times that figure (386.2) (ECB, 2020). However, a survey by the Association of German Banks (2020) in April of this year shows a positive trend in cashless payment in shops.

559. The pandemic caused a rapid increase in **workplace flexibility**. Mobile work supported by digital technologies has increased considerably in Germany this year. For instance, 27.7 % of employees started working from home during the pandemic (Eurofund, 2020).

The **proportion of people working from home** in Germany before the pandemic was below average in the EU. ↘ CHART 93 The number of people who can basically do their job completely from home depends on the economic structure and the required tasks to be performed. However, the relevant working-from-home potential (Dingel and Neiman, 2020) shows that some countries with a potential as high as Germany had a larger proportion of people working from home before the pandemic. Initial survey results reveal that some of the increase in working from home could prevail after the pandemic (Hoffmann et al., 2020). The marked increase in Internet searches for video conferencing providers also indicates the heavy use of digital video conferencing systems for mobile work. ↘ CHART 92 RIGHT

560. But it is not possible for all employees to work from home, due to the nature of their tasks. Nor does remote working offer the personal contacts and business travel that contribute to knowledge dissemination (Coscia et al., 2020). Nevertheless, the increase in working from home has **productivity potentials** (Bloom et al., 2015; OECD, 2020e; Viete and Erdsiek, 2020). It could reduce commuter traf-

fic and ease the housing shortage in metropolitan areas, as well as creating economic development opportunities outside such areas (Garnadt et al., 2020).

4. Macroeconomic impact of digitalisation

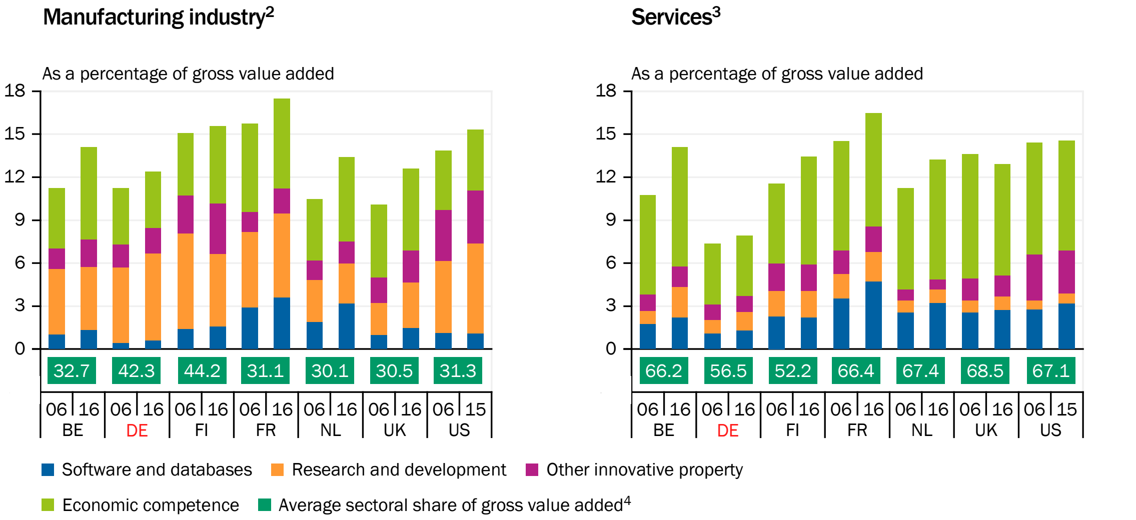
561. The trend of declining growth in both labour productivity and total factor productivity despite ongoing technological innovation since the mid-2000s is currently being discussed as a **productivity paradox** (GCEE Annual Report 2019 items 175 ff.). Pessimistic **explanations** assume **declining technological potential** and thus lower returns on R&D (Bloom et al., 2017; Gordon and Sayed, 2020). However, other discussions centre on **problems of measuring** output in the form of digital goods (Syverson, 2017; Brynjolfsson et al., 2020a), **adoption delays** in diffusion of digital technologies (Bajgar et al., 2019a), a **structural change** towards a less productive service sector and **mutually neutralising effects** of an increase in labour productivity and labour demand through improvements in ICT (Elstner et al., 2018; GCEE Annual Report 2019 items 175 ff.). However, none of these approaches can be identified as the sole explanation for the phenomenon of declining productivity growth rates based on existing empirical evidence (Peters et al., 2018).

562. Although **ICT** contributed little to **productivity growth** in an early period of diffusion during the 1980s (Jorgenson and Stiroh, 1995), it has been a driver of productivity growth with considerable investment in digital technologies since the 1990s, particularly in the United States (Jorgenson et al., 2008; van Ark et al., 2008). **Studies based on firm-level data**, in particular,indicate **positive productivity effects of ICT use** (Cardona et al., 2013). Dhyne et al. (2018) and Bloom et al. (2019a) show, on the basis of detailed Belgian and US firm-level data, that ICT investment due to positive productivity returns explains about 10 % and 12 %, respectively, of the productivity variation across companies (measured by the interdecile range of TFP and labour productivity). Dhyne et al. (2018) also find that, particularly after 2008, the positive productivity effects of ICT found at the firm level were much lower at the aggregate level. This is partly due to low ICT investments in general, and partly to misallocation of ICT investment, i.e. low use of ICT in firms with high marginal returns relative to costs.

563. Firm-level studies also show marked differences between the ability of individual firms to reap the productivity potential of ICT (Bresnahan et al., 2002; Bloom et al., 2012). A key finding of this research is that the productivity returns from ICT adoption depend a great deal on **complementary investments in intangible production factors**, primarily organisation of the production process, employee skills and development of innovative applications for general purpose technologies (Van Reenen et al., 2010). However, these organisational adjustments are often lengthy and expensive processes.

564. By international standards, Germany's level of **investment in corresponding intangible production factors is low**, particularly in the service sector (GCEE Annual Report 2019 items 305 ff.).↘ CHART 94 In the data used for analyses on this topic, intangible factors of production include expenditure on R&D, on software

↘ CHART 94
Low level of investment in intangible factors of production in Germany[1]



1 – Investment in intangible production factors in relation to the gross value added of the respective sector. The official gross value added figures have been corrected to include the value added comprised in the intangible production factors. BE-Belgium, DE-Germany, FI-Finland, FR-France, NL-Netherlands, UK-United Kingdom, US-USA. 2 – NACE Rev. 2 sections B–F. 3 – NACE Rev. 2 sections G–S. 4 – Average share, expressed as a percentage of the respective sector in the total gross value added of the respective country from 2006 to 2016; for the USA from 2006 to 2015.

Sources: INTAN-Invest (2020), own calculations

and databases, investment in economic skills, such as work organisation and vocational training, and other assets relevant to innovation, such as designs (Corrado et al., 2005, 2016). Overall, studies based on aggregate and sectoral data for the United States and the European Union indicate positive productivity effects of intangible production factors (Corrado et al., 2009; Niebel et al., 2017; Adarov and Stehrer, 2019). M. Zimmermann (2020) and Belitz et al. (2017) document positive effects on output and TFP based on German firm-level data. Due to the positive complementarities between ICT capital and such intangible production factors (Brynjolfsson and Hitt, 2000), the latter have a stronger productive effect in ICT-intensive industries (Chen et al., 2016). In addition to lower growth contributions from ICT investments in Europe than in the United States (van Ark et al., 2008), intangible production factors explain the divergence in productivity growth between the two regions (Corrado et al., 2016).

565. Brynjolfsson et al. (2020b) argue that some types of **complementary investments in intangible production factors**, such as for business process transformation and employee education and training, are **difficult to measure**. This initially leads to underestimation of aggregate productivity growth, but to to overestimation in later phases of the diffusion of general purpose technologies.

566. The decline in aggregate productivity growth has been accompanied by a widening **gap between a few highly productive companies and a large number of low-productivity laggards** (Andrews et al., 2016; Berlingeri et al., 2019). This trend is particularly pronounced in ICT-intensive industrial sectors (Bajgar et al., 2019b). ↘ ITEM 541

567. Delays in adoption can be observed in the diffusion of ICT in Germany (GCEE Annual Report 2019 item 180). The low use of digital technologies, above all **in**

SMEs, may be related to **low absorptive capacity**, i.e. the **capability of complementary investments** in human capital and reorientation of business processes and work organisation. Germany is also lagging behind in terms of broadband Internet connections, which are essential for many data-based applications. ↘ ITEM 575 Not least a shortage of IT experts, primarily in SMEs, has been noted in recent years (BA, 2019; Czernich et al., 2019).

568. **Computerised information** as a factor of production has defining characteristics that distinguish it from other goods (GCEE Annual Report 2019 items 306 ff.). It is **scalable** and can be reused at **very low marginal costs**. In addition, digital business models have **high fixed costs**. Both enable increasing economies of scale, **favour large companies** (Sutton, 1991) and result in higher concentration of economic activity in superstar firms. This is often regarded as the reason for various macroeconomic trends described in the literature (Akcigit and Ates, 2020), such as growing concentration in many markets, higher price mark-ups (Van Reenen, 2018) and a declining labour share (Autor et al., 2017).

569. **Implementation of new technologies is accompanied by new skill requirements** in companies. This increases the demand for skilled workers and creates incentives for further professional training (Bresnahan et al., 2002; Spitz-Oener, 2006; Goos et al., 2019; Arntz et al., 2020). The employment effects of new technologies (GCEE Annual Report 2017 items 755 ff.) depend on three key factors: technology diffusion, employee flexibility and creation of new jobs. The currently observed moderate diffusion rate of technologies could be due to a lack of trained specialists, which slows down the implementation of new technologies (Arntz et al., 2020).

IV. SEIZING THE OPPORTUNITIES OF DIGITALISATION AND BOOSTING INNOVATION

570. **Complementary investments** and a suitable **framework** are essential in order to take advantage of the opportunities digitalisation offers. Diffusion of state-of-the-art digital technologies can be supported by further expanding the digital infrastructure. There is also a need to reinforce digital literacy in school education, vocational training, as well as on-the-job training throughout the working life in order to use and develop digital working methods, products and services. To foster development of new technologies, a competitive environment is required that allows innovative start-ups to enter the market and boosts their financing options.

1. Expanding the digital infrastructure

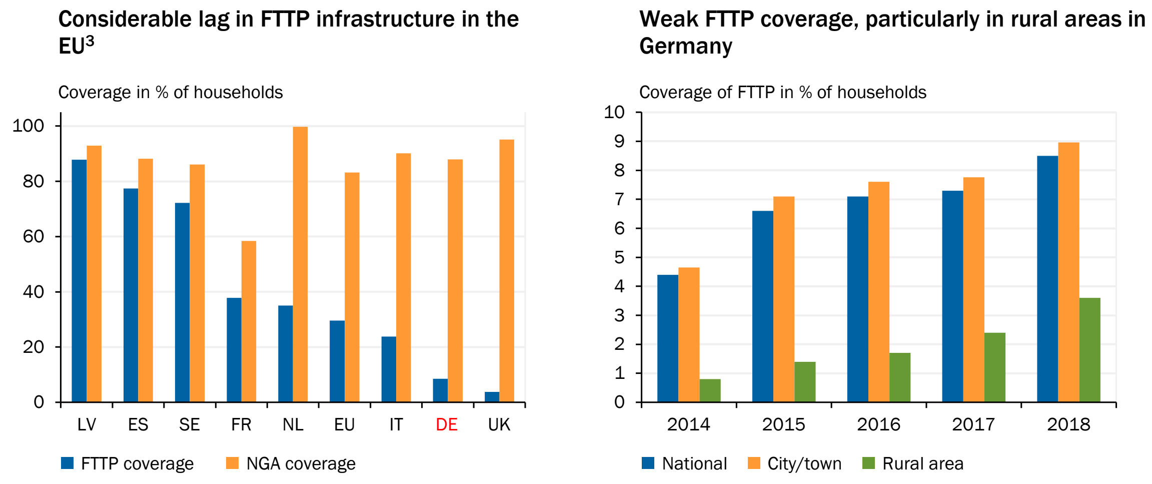
571. Technological innovations in autonomous driving, Industry 4.0 and e-health will place great demands on the bandwidth and reliability of the **digital infrastructure** in future. Universal access to **high-speed Internet** is therefore becoming the key criterion for Germany as a business location.

572. **Mobile broadband networks** are growing in importance. Since the expansion of 4G networks, they have been delivering bandwidths comparable to those of hybrid wired network architectures. In the next few years the development of **5G networks** will enable a convergence between mobile and fixed networks for the first time (Bertschek and Briglauer, 2018). Many of the digital applications currently in development, such as Industry 4.0 applications or networked and autonomous driving, require widespread availability of powerful 5G networks (Elbanna, 2019). For this reason, a dense network of mobile phone masts established on a **fibre-optic network** will be necessary (Ilgmann and Störr, 2020).

573. As part of its **Digital Strategy 2025**, the Federal Government is pursuing the ambitious goal of setting up a **nationwide** fixed network infrastructure with Gigabit speed by 2025 (BMWi, 2016). In the past, expansion targets have been defined based solely on the performance of the infrastructure, irrespective of the connection technology. Now, **fibre-optic connections** to the home are prioritised for the first time (fibre to the premises, or **FTTP**; CDU, CSU and SPD, 2018; BMVI, 2020). The Federal Government's mobile communications strategy also aims to close the gaps in the 4G network and develop Germany into the **lead market for 5G technologies** (BMVI, 2019).

574. Since liberalisation of the telecommunications services market at the end of the 1990s, **expansion of the Internet infrastructure has been the responsibility** of various competitors in addition to Deutsche Telekom as the former state-owned monopoly operator of telephone networks. The largest **network operators** by customer share of stationary connections, besides Deutsche Telekom (38.9 %), are Vodafone/Unitymedia (30.3 %), 1&1 (12.3 %) and Telefónica Deutschland (6.2 %) (DIALOG CONSULT and VATM, 2020).

↘ CHART 95
Availability of FTTP[1] and NGA[2] broadband infrastructure in 2018



1 – Fibre to the premises. 2 – Next Generation Access Network comprises VDSL, FTTP, DOCSIS 3.0. 3 – LV-Latvia, ES-Spain, SE-Sweden, FR-France, NL-Netherlands, EU-European Union 28 excluding Greece, IT-Italy, DE-Germany, UK-United Kingdom.

Sources: European Commission, own calculations

575. Measured by availability in households, Germany is now slightly above the European average in expansion of fibre-optic **Next Generation Access (NGA) networks**, which can deliver reception bandwidths of up to 1 Gbit/s.↘ CHART 95 LEFT However, a large share of these connections are delivered via hybrid technologies based on existing first-generation networks such as telephone or television cable networks (VDSL, DOCSIS) (European Commission, 2020d). In contrast, **provision of FTTP connections**, which deliver the highest bandwidths, is **low** in Germany. Coverage is weak in rural areas in particular, where expansion is often uneconomical for network operators (European Commission, 2019b). ↘ CHART 95 RIGHT With FTTP connection availability for less than 10 % of households in 2018 and a high imbalance between urban and rural areas in Germany, there appears a great need for action to achieve the nationwide coverage targets formulated in the coalition agreement by 2025.

576. In addition to an undersupply in certain areas, **low usage rates of high bandwidth connections** are currently noted among end customers (FTTH Council Europe, 2020). One frequently discussed reason is users' low willingness to pay for high bandwidths (Ilgmann, 2019; Monopolies Commission, 2019). A key explanation for the relatively low level of expansion of and demand for FTTP connections in Germany is the **high-quality first-generation broadband infrastructure**, the correspondingly high opportunity costs of an investment in FTTP infrastructure on the supply side, and the currently low additional benefits for end users when switching (Briglauer and Gugler, 2013; Bertschek and Briglauer, 2018).

577. The broadband infrastructure generates positive externalities between users of broadband services on the one hand and the providers of such services on the other. A lack of nationwide broadband coverage and therefore a low number of broadband users could result in lower investment in complementary innovations and new business models. Such **network externalities** can justify government incentives for broadband expansion on both the supply and the demand sides (Briglauer and Schmitz, 2019). In particular, the **government** should take a **coordinating function** between network operators, end customers and digital service providers.

578. A fundamental problem in network expansion is the **high cost of providing the service** compounded by **great uncertainty** about future local **demand and technological advances**. Market solutions for Internet expansion by private network operators therefore yield insufficient investment and undersupply, particularly in rural areas, due to low profitability. This creates a socially undesirable digital gap between urban and rural areas (Homann et al., 2018) and may necessitate regional supply-side funding for network expansion (Gerpott, 2017).

Germany's federal funding programme, which promotes expansion by giving grants to local authorities, has been prioritising Gigabit-capable connections since 2018 (BMVI, 2020). However, the low take-up rate has been a problem since the programme's launch (German Bundestag, 2018). This has often been attributed to a high level of **bureaucracy** in approval procedures (Monopolies Commission, 2019).

579. Expansion of the mobile communication infrastructure in Germany was previously slowed by time-consuming approval processes for the construction of radio masts (Falck et al., 2019b). The **current economic stimulus package** includes €5 billion capital for the state-owned mobile communication infrastructure agency (Mobilfunkinfrastrukturgesellschaft, or MIG), which is to be newly founded (Coalition Committee, 2020). It is intended to function as a coordinating body to drive the 5G rollout in dead zones not served by mobile network operators and to support local authorities in planning or by providing real estate. However, MIG has already been the subject of much criticism, as the demarcation of its tasks from those of other institutions responsible for infrastructure expansion, such as the Federal Ministry of Transport and Digital Infrastructure (BMVI) and ministries on the state level, appears unclear (Ilgmann and Störr, 2020). Moreover, the Federal Government has earmarked up to €2 billion in funding for companies developing software-defined networking (SDN) technologies. The stimulus package is also aimed at improving funding schemes and **reducing their red tape**. Reducing bureaucratic hurdles appears to be an important measure, particularly given the low take-up rates in the past. Building a denser mobile phone mast network connected to the fibre optic infrastructure should be accelerated due to the great importance of a nationwide 5G network for innovation, such as in Industry 4.0, and in networked and autonomous driving.

2. Digital literacy training

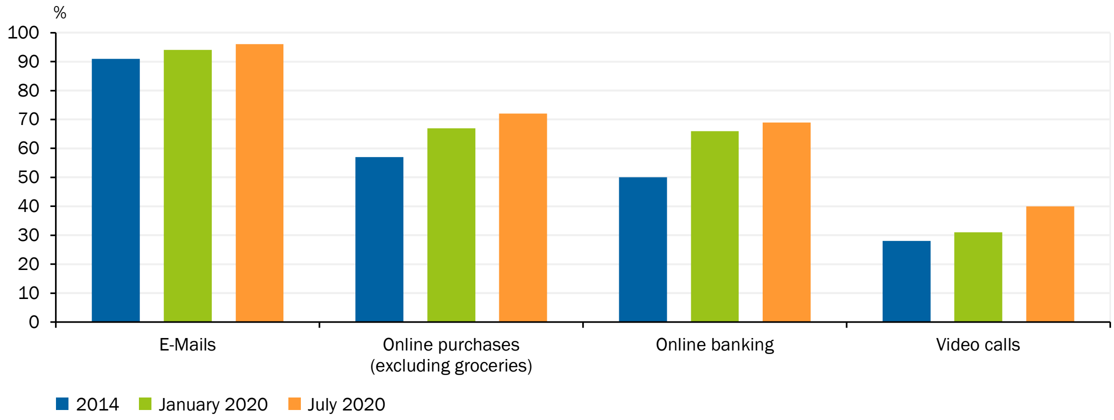
580. The **acquisition of digital literacy basics** should be an essential part of compulsory education. These include skills in locating, interpreting and creating digital content, and interacting online (Burns and Gottschalk, 2019), as well as the ability to collect, manage and critically evaluate data (data literacy) (Bocconi et al., 2016; García-Peñalvo and Mendes, 2018). Moreover, general skills, such as **analytical thinking and problem-solving** form a vital basis for performing highly-skilled activities in the field of IT and digitalisation. In addition, learning programming languages for practical applications at an early age should be promoted in schools on a nationwide basis and receive greater support (GCEE Annual Report 2017 item 813). Acquisition of basic skills could result in more effective use of digital technologies in the labour market (Lye and Koh, 2014; OECD, 2016; Paniagua and Istance, 2018; Falck et al., 2020).

581. The earlier **digital technologies** are emphasised at school, the faster pupils are likely to be attracted to these subjects. However, provision of digital media and digital devices in the classroom does not automatically lead to better performance of pupils (Angrist and Lavy, 2002; Leuven et al., 2007; Escueta et al., 2017). In addition to the provision of materials in schools, **training and further education of teachers** in using digital methods, developing digital skills and assessing the opportunities and risks of digital technologies are particularly necessary. ↘ ITEM 555 Rolling out digitalisation in schools also calls for an increase in staff capacities to set up and maintain the ICT infrastructure. It further requires **availability of broadband Internet connections** in schools and Wi-Fi in **classrooms** (European Commission, 2020e). The **coronavirus pandemic** has shown that there is a **serious lag** in all the areas addressed above.↘ ITEM 554

↘ CHART 96

Use of internet services by persons aged 65 and above[1]

Slight increase in digitalisastion in this user group



1 – Internet users aged 65 and above (population N=499 in 2014, N=516 in January 2020, N=522 in July 2020), response to the question: What do you do online, at least occasionally?

Source: Bitkom Research

582. Digital literacy training should not end with schooling. Digitalisation is changing job descriptions and thus also the skills required (Spitz-Oener, 2006; Janssen et al., 2018; Expertise 2011 items 185 ff.). These needs should be addressed through a comprehensive offering of **digital training**. The quality of education, on-the-job training and **lifelong learning** should be improved by means of increased competition between educational institutions (GCEE Annual Report 2017 items 820 ff.).

The Federal Government's National Skills Strategy (Nationale Weiterbildungsstrategie) provided an impetus towards this objective in 2019 (BMBF and BMAS, 2019). For example, measures were proposed to expand the procedures for assessing and certifying informally acquired skills nationwide, to increase upgrading training assistance (Aufstiegs-BAföG) and to support on-the-job training in companies. A first assessment of the National Skills Strategy indicates, however, that obstacles to further training have not yet been adequately addressed (Heinrich Böll Foundation and Bertelsmann Foundation, 2020). The Federal Government plans to review the status of implementation in 2021, along with the objectives of the National Skills Strategy, which will be further developed if necessary.

Lifelong learning may, moreover, allow **professional reorientation** through vocational training or studies at universities during working life, and should also include **senior citizens**. ↘ ITEM 640 Enabling this group to use digital technologies not only makes for a more inclusive society, but also ensures that this age-group has access to a greater range of competing offers. Companies can tap new business areas and investments in digital products can pay off more quickly as a result. Representative survey results conducted by Bitkom (2020b) indicate a slight increase in the use of Internet services by older people during the Covid pandemic. ↘ CHART 96

3. Harnessing the potential of digitalisation

583. Financial incentives made by the government promote investment in physical capital in particular (OECD, 2019b). However, current technological developments are increasingly driven by digital services such as cloud computing, which are not addressed by these incentives (Andres et al., 2020). **State support should therefore** also be aimed at **complementary intangible production factors** and **external services** such as licensing, external consultancy, and training in order to boost diffusion of digital technologies. This has been addressed, for example, in the Federal Government's "Digital jetzt" programme aimed at SMEs, which combines subsidies for investment in digital technologies and in digital skills training of employees (BMWi, 2020a).

Expanding digitalisation of public administration and the options for digital interaction with authorities could foster digitalisation in small companies. Such an expansion would result in increasing demand for digital products and services, which would motivate companies to expand and develop their offerings. ↘ ITEM 551

584. Due to the importance of large, uniformly regulated markets for scaling up, **strengthening the European Digital Single Market** would facilitate developing digital business models (GCEE Annual Report 2019 items 313 ff.). One step towards achieving this is the **European data strategy** published in February 2020, which aims to create a single market for data. The strategy includes four pillars, which aim to increase the EU share of the data economy until it equals at least the EU share of the global economy (Bertschek, 2020; European Commission, 2020f). The first two pillars are intended to establish a cross-sectoral data governance framework and foster investment into the data infrastructure as well as interoperable cross-sectoral data spaces. The German data infrastructure initiative GAIA-X could contribute to this end (GCEE Annual Report 2019 item 314). Additional data economy skills of employees and SMEs are to be improved under the third pillar. The fourth pillar consists of creating common European data spaces, taking into account sectoral differences in strategic areas such as industry, healthcare and public administration.

The **Digital Services Act** (European Parliament, 2020a, 2020b), which revises, among other things, the responsibilities of online platforms previously governed by the Directive on Electronic Commerce, is also expected to provide for concrete steps towards harmonisation (European Parliament and Council of the European Union, 2000). The expected revision of the liability regime for online intermediaries in relation to third-party content available on their platforms should take the impact on small and young companies into account, in line with the EU Copyright Directive (European Parliament and Council of the European Union, 2019). Content review and moderation is comparatively more expensive and time-consuming for small and young businesses.

585. Another important prerequisite for digital economy dynamism is the competition law, which needs to address the special situations arising from network effects.

Given the dominance of large digital platforms, it is important to ensure the **competitive openness of digital markets** and the **contestability of entrenched positions of power**, and thereby to facilitate market entry for new competitors (Competition Law 4.0 Commission, 2019; GCEE Annual Report 2019 items 315 ff.). **Interoperability** and **data portability** between different applications and platforms as well as **data sovereignty of consumers** are crucial in enabling them to switch easily between applications and platforms. It is also important to prevent unjustified preferential treatment of platform operators' own products and services, in order to facilitate innovation and offer of new competing products and services on platforms.

The German government's draft bill of the **10th amendment to the Act against Restraints of Competition (Gesetz gegen Wettbewerbsbeschränkungen - GWB)** dated 9 September 2020 addresses these aspects. Simultaneously the issue is discussed with respect to the **further development of competition law at EU level**. Concerning market-dominant platforms at EU level, a regime is also to be developed under the Digital Services Act stipulating actions prohibited for these companies and rules they are to comply with. Discussion is also in progress on the development of a new competition tool based on the UK Markets Regime (Competition & Markets Authority - CMA, 2017) in the United Kingdom. As things currently stand, both tools – which were initially discussed separately – will form two complementary pillars of a single draft law to regulate digital markets (Vestager, 2020) However, the draft bill is to be presented on 2 December 2020, and therefore cannot yet be conclusively assessed.

586. Obstacles to innovation include **data security problems** and the danger of cyber attacks (Commission of Experts for Research and Innovation (Expertenkommission Forschung und Innovation – EFI), 2020). A large volume of production and business-critical data is generated in the German manufacturing industry in particular, which calls for particularly stringent data security requirements (Saam et al., 2016). The increased generation of personal data by smart devices in private use raises the risk of cyber crime (European Court of Auditors, 2019). At the same time, the high demand for **cyber security solutions** creates value-added potential (EFI, 2020). In accordance with the 2018 coalition agreement, the Federal Government has been funding R&D projects in this field through the Agency for Innovation in Cyber Security since 2020 (FMI, 2020). Moreover, a technical solution for improving data privacy and data sovereignty is also being sought as part of the GAIA-X project (GCEE Annual Report 2019 item 314) – the German initiative for developing a European cloud infrastructure (BMWi, 2020b). This could be of interest particularly to small and medium-sized enterprises, which shy away from using digital services, such as in cloud solutions, because of security concerns.

587. Last but not least, any concerns raised by the public at large ought to be taken seriously. The way to use digital technologies while complying with the necessary security standards should be discussed **with all social stakeholders**. Companies often cite Germany's strict data protection requirements as an obstacle to innovation (Goldfarb and Tucker, 2012; Erdsiek, 2020). Yet the issue of data security and data sovereignty is also important to consumers. With the entry into force

of the **General Data Protection Regulation (GDPR)** in 2018, the EU took a major step towards **data protection, data sovereignty** and **free movement of data** by international standards (European Parliament and Council of the European Union, 2016). However, implementation of the GDPR is expensive and time-consuming (Erdsiek, 2020), making it difficult to bear, more so for SMEs, which could therefore favour large companies.

4. Increasing innovation incentives

588. The research allowance was introduced to increase innovation incentives for SMEs. ↘ ITEM 516 As part of the Zukunftspaket – the long-term orientated part of the economic stimulus programme –, the upper limit of the tax assessment basis was raised from €2 million to €4 million. However, this rise will benefit larger companies in particular and likely result in windfall gains. An increase of 10 percentage points for medium-sized enterprises and 20 percentage points for small enterprises to the maximum rates allowed under Article 25 of the General Block Exemption Regulation (GBER) for supporting experimental development would have been more appropriate to **boost research incentives** and the **liquidity of innovative SMEs**.

589. **Further expansion of the European Research Area** would help to increase **synergies** at European level (GCEE Annual Report 2019 item 301). The budget for the EU Framework Programme for Research and Innovation for the years 2021 to 2027 "Horizon Europe" will be increased compared to the previous Framework Programme "Horizon 2020", from around €70 billion to €85.5 billion (Council of the European Union, 2020). ↘ ITEM 279 However, this increase is considerably lower than the approximately €120 billion recommended by the High-Level Expert Group (2017) and called for by the European Parliament. It will only be partly financed by the Multiannual Financial Framework, but partly also by the recovery fund. Given the EU-wide R&D rate of 2.11 % of GDP in 2018, this development is clearly at odds with the objective of achieving an R&D rate of 3 % by 2020, as set out in the EU's Europe 2020 strategy (European Commission, 2010).

590. In addition to conventional supply-oriented innovation policy measures of project funding and fiscal R&D support, the government could offer demand-side incentives for innovation by **anchoring innovation criteria more firmly in public procurement**, along with the traditional criteria of economical and efficient use of budget funds. Changes in public procurement law in Germany and the EU since 2009 and 2014, respectively, have led to a greater focus on functional, solution-oriented criteria in public tenders. In Germany, innovation-oriented public procurements have resulted in higher sales of innovative products at companies that received the contracts (Czarnitzki et al., 2020). One obstacle to innovation-oriented procurement is, however, a lack of sufficiently qualified administrative staff (OECD, 2017). In Germany, the Competence Centre for Innovative Procurement (Kompetenzzentrum innovative Beschaffung - KOINNO) was established in 2013 to train and advise decision-makers on innovation-oriented procurement. Strengthening this initiative to improve innovation-oriented procurement skills at the decision-making level, and anchoring innovative thinking more firmly at

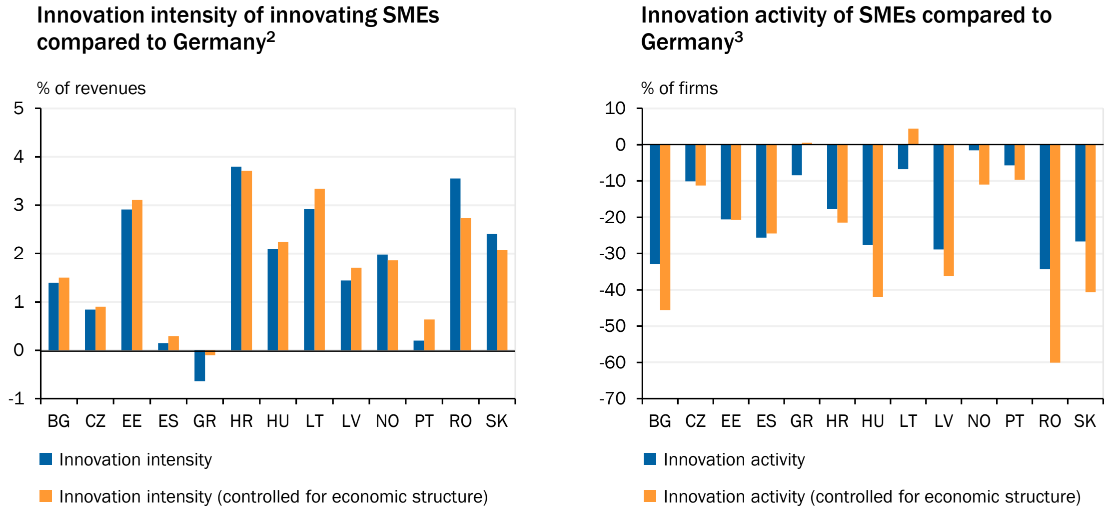
administration management level, could substantially increase the market for innovations.

591. **Knowledge and technology transfer** play an important role in unlocking the full social benefits of public academic research (Wissenschaftsrat, 2016). ↘ ITEM 496 The Efforts made in recent years to **strengthen** such transfer should therefore be continued. Implementing the transfer as an additional objective in the higher education strategy and defining responsibilities at management level could be a contributing factor (Wissenschaftsrat, 2016). The transfer audit on transfer practice conducted by the Stifterverband association of German companies at almost 50 higher education institutions in Germany suggests that the institution-specific evaluation concepts proposed by the Wissenschaftsrat (2016), in particular the definition of quantitative and qualitative transfer targets, should help to evaluate and further develop transfer activities (Frank and Lehmann-Brauns, 2020). Furthermore, professionalisation of technology transfer in special transfer offices with professionally trained transfer managers and an incentive system for researchers to transfer academic knowledge would be helpful. The focus should be on the social added value created by the transfer, and not on generating licensing income.

APPENDIX

↘ CHART 97

Economic structure barely influences differences in innovation intensity[1]



1 – Firms with less than 250 employees. BG-Bulgaria, CZ-Czech Republic, EE-Estonia, ES-Spain, GR-Greece, HR-Croatia, HU-Hungary, LT-Lithuania, LV-Latvia, NO-Norway, PT-Portugal, RO-Romania, SK-Slovakia. 2 – Depicted is the country effect of a with sales weighted extrapolation factors weighted regression of innovation intensity (ratio of innovation expenditure and sales) on country dummies or country and economic sector dummies respectively. Germany is taken as base country (effect = 0). The sample only includes firms that have conducted a successful innovation project. 3 – Depicted is the country effect of a with extrapolation factors weighted regression of the indicator "Successful completion of an innovation project" on country dummies or country and economic sector dummies respectively. Germany is taken as base country (effect = 0).

Sources: Eurostat Community Innovation Survey 2014, own calculations

↘ TABLE 18

4IR technology fields by sector

Technology field	Definition	Example
Core technology fields		
Hardware	Basic hardware technology	Sensors, advanced memories, processors, adaptive displays
Software	Basic software technology	Intelligent cloud storage and computing structures, adaptive databases, mobile operating systems, virtualisation
Connectivity	Basic connectivity systems	Network protocols for massively connected devices, adaptive wireless data systems
Enabling technology fields		
Analytics	Enabling the interpretation of information	Diagnostic systems für Big Data
Security	Enabling the security of data or physical objects	Adaptive security systems, intelligent safety systems
Artificial intelligence	Enabling machine understanding	Machine learning, neural networks
Position determination	Enabling the determination of the position of objects	Enhanced GPS, device to device relative and absolute positioning
Power supply	Enabling intelligent power handling	Situation-aware charging systems
Three-dimensional support systems	Ernabling the realisation of physical or simulated 3D systems	3D printers and scanners for parts manufacture, automated 3D design and simulation
User interfaces	Enabling the display and input of information	Virtual reality, information display in eyewear
Application domains		
Home	Applications for the home environment	Alarm systems, intelligent lighting and heating
Personal	Applications pertaining to the individual	Personal health monitoring devices, smart wearables, entertainment devices
Enterprises	Applications for business enterprises	Intelligent retail and healthcare systems, autonomous office systems
Manufacture	Applications for industrial manufacture	Smart factories, intelligent robotics
Infrastructure	Applications for infrastructure	Intelligent energy distribution and transport net-works, intelligent lighting and heating systems
Vehicles	Applications for moving vehicles	Autonomous driving, vehicle fleet navigation devices

Sources: European Patent Office, own presentation

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