

Chapter 7 Intangible investment, innovation and digitalisation EUROPEAN INVESTMENT BANK INVESTMENT REPORT 2020/2021

Building a smart and green Europe in the COVID-19 era

Part II Investing in the transition to a green and smart economy

Chapter 7 Intangible investment, innovation and digitalisation



Investment report 2020/2021: Building a smart and green Europe in the COVID-19 era

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About the Report

The EIB annual report on Investment and Investment Finance is a product of the EIB Economics Department, providing a comprehensive overview of the developments and drivers of investment and its finance in the European Union. It combines an analysis and understanding of key market trends and developments with a more in-depth thematic focus, which this year is devoted to European progress towards a smart and green future in a post-COVID-19 world. The report draws extensively on the results of the annual EIB Investment Survey (EIBIS) and the EIB Municipality Survey. It complements internal EIB analysis with contributions from leading experts in the field.

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The mission of the EIB Economics Department is to provide economic analyses and studies to support the Bank in its operations and in the definition of its positioning, strategy and policy. The Department, a team of 40 economists, is headed by Debora Revoltella, Director of Economics.

Main contributors to this year's report

Report Director: Debora Revoltella

Report Coordinators and Reviewers: Pedro de Lima and Atanas Kolev

Introduction: Atanas Kolev.

- Chapter 1: Atanas Kolev (lead author), Laurent Maurin (lead author), Koray Alper, Luca Gattini, Jochen Schanz and Patricia Wruuck.
- Chapter 2: Atanas Kolev (lead author), Andrea Brasili, Peter McGoldrick and Jochen Schanz.
- Chapter 3: Laurent Maurin (lead author), Joel Auber, Frank Betz, Rozalia Pal and Patricia Wruuck, together with Antonia Botsario, Salome Gvetadze, Helmut Kraemer-Eis, Frank Lang and Wouter Torfs (all European Investment Fund, Research and Market Analysis).
- Chapter 4: Fotios Kalantzis (lead author), Andrea Brasili and Annamaria Tueske.
- Chapter 5: Fotios Kalantzis (lead author) and Hanna Niczyporuk (New York University).
- Chapter 6: Laurent Maurin (lead author), Giovanni Barci, Emmanouil Davradakis, Aron Gereben, Annamaria Tueske and Marcin Wolski.
- Chapter 7: Christoph Weiss (lead author), Julie Delanote, Peter Harasztosi, Désirée Rückert, Antilia Virginie, Sara Amoroso (European Commission, Joint Research Centre, Box A), Petros Gkotsis (European Commission, Joint Research Centre, Box A) and Nicola Grassano (European Commission, Joint Research Centre, Box A).
- Chapter 8: Julie Delanote (lead author), Désirée Rückert (lead author), Peter Harasztosi and Julie Callaert (ECOOM, KU Leuven, collaboration for PATSTAT data preparation, Box A).
- Chapter 9: Peter McGoldrick (lead author), Maïa Debs, Julie Delanote, Atanas Kolev and Désirée Rückert.
- Chapter 10: Patricia Wruuck (lead author), Aron Gereben, Peter McGoldrick, Désirée Rückert, Annamaria Tueske, Daniel Wetzel (International Energy Agency, Box B) and Marcin Wolski.

Scientific advisory committee: Giorgio Barba Navaretti (Università degli Studi di Milano), Eric Bartelsman (Tinbergen Institute), Catherine L. Mann (Citi), Steven Ongena (University of Zurich), Pier Carlo Padoan, Peter Praet, Jan Svejnar (Columbia University) and Reinhilde Veugelers (KU Leuven).

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Chapter 7 Intangible investment, innovation and digitalisation



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Chapter 7

Intangible investment, innovation and digitalisation

The coronavirus pandemic crisis has led to wider recognition of the importance of innovation and digital transformation. According to the latest results of the EIB Investment Survey (EIBIS), most firms in the European Union and the United States expect the COVID-19 outbreak to have a long-term impact on the use of digital technologies, with more than a third of firms expecting it to affect their service and product portfolio or supply chain.

With investment collapsing due to the pandemic, many firms may fail to adapt to the new digital reality. At the same time, a sharp drop in sales may drive them to focus on short-term survival strategies. They may delay or cancel investment in innovation activities, which will impede the creation, transfer, and adoption of new technologies. EU firms need to reassess their operating context and proactively invest, innovate and adapt to ensure their sustainability and ability to thrive in the new environment. This will require significant investment across the European Union and a policy framework conducive to innovation and the adoption of innovation.

The global innovation landscape is changing rapidly because of the growing importance of digital technologies and the emergence of China, which has joined the United States and Europe as a global player in research and development (R&D). While remaining at the forefront of technology, the European Union is investing less in R&D as a percentage of gross domestic product (GDP) than other major economies. This lower level of R&D may have negative implications for innovation and long-term growth. Lower business R&D spending is largely behind the R&D gap in the European Union.

The digital transformation is affecting virtually all sectors of the economy. European companies are global leaders in various traditional industries, those without digital origins. But the European Union is less present in fast-growing digital sectors such as software and computer services. Several Chinese companies have joined the ranks of top US firms as important technological players. Meanwhile, the European Union does not appear to be generating many new innovation leaders, especially in the digital sector, potentially jeopardising the long-term competitiveness of Europe. A weak European digital sector also means that EU companies and citizens will lack ownership of their data, leaving it to be controlled outside the European Union.

The European Union is lagging behind not only in digital innovation, but also in digital adoption. Digital adoption rates are lower for EU firms than US firms. Firms that have implemented digital technologies, especially those using multiple technologies, tend to perform better than non-digital firms. They invest more, are more innovative, have better management practices, grow faster and create higher paying jobs. Digital firms are also more likely to invest to meet the challenges of climate change, such as preparing for extreme weather events and reducing their carbon emissions. That being said, EU firms tend to invest much more in these areas than US firms, despite having lower digital adoption rates.

To foster the green recovery and address the long-term impact of COVID-19, the European Union will need to create better conditions for innovation and digitalisation. Intangible investment, such as R&D, software and databases, training of employees and organisational capital, and digital technologies are rising in importance. Public policies should not only focus on supporting R&D activities, but should also consider regulations affecting competition, the environment, data and trade to improve the diffusion of innovation. While governments tend to weigh different policies and their potential impact on innovation activities separately, recognising the complementary nature of policy interventions is key to finding the right mix. Getting the balance right is especially relevant for firms that are not at the cutting-edge of technology, as the COVID-19 crisis is likely to exacerbate the digital divide between them and more technically savvy firms.

Introduction

The COVID-19 crisis has led to wider recognition of the importance of innovation and digital transformation. According to the latest results of the EIBIS, most firms in the European Union and the United States expect the coronavirus pandemic to have a long-term impact on the use of digital technologies. Businesses will rely on technology to prevent disruptions and to improve communication with customers, suppliers and employees. More than a third of firms expect the pandemic to affect their service and product portfolio or supply chain. With investment collapsing due to the COVID-19 crisis, many firms may fail to adapt to the new digital reality. A falloff in revenue will squeeze their liquidity and may force them to focus on short-term survival strategies (Revoltella, Maurin and Pal, 2020). They may delay or cancel investment in innovation activities, which will impede the creation, transfer, and adoption of new technologies (World Bank, 2020). EU firms therefore need to reassess their operating context and invest, innovate and adapt to ensure their sustainability and ability to thrive in the new environment. This will require significant investment across the European Union and a policy framework conducive to innovation and the adoption of innovation.

This chapter provides an overview of recent trends in global R&D expenditure and the investment activities of innovative companies. It highlights the changes in the global innovation landscape, with China emerging as a new player and digital innovation disrupting many sectors that were not born digital. The chapter discusses the rapid adoption of digital technologies in the European Union and the United States, the impact on the performance of firms and the constraints they face. Firms that have implemented digital technologies, especially those using multiple technologies, tend to perform better than non-digital firms. They invest more, are more innovative, have better management practices, grow faster and create higher paying jobs. Digital firms are also more likely to invest in tackling climate change challenges, an area in which EU firms invest much more often than US firms. The chapter concludes by highlighting the importance of developing effective public policies that incentivise investment in innovation and digitalisation to address the COVID-19 crisis and foster the green transition.

Innovation in advanced economies

Innovation and digital transformation can help limit the negative consequences of the coronavirus outbreak. Investment in innovation – especially in the pharmaceutical and biotechnology sectors, and more generally in the health sector – is critical to finding an effective treatment rapidly and limiting the virus's spread. Digital technologies are also key to adapting to a new environment where people work remotely to respect physical distancing requirements.

The short-term economic recovery can be supported with investments in physical and human capital, but in the long term, economic growth will depend on innovations that make capital more productive. Almost half of firms in the European Union and United States expect to invest less and delay or abandon investment plans in 2020 as a result of the pandemic, according to the latest EIBIS results. Most governments have responded with indirect measures to support investment while protecting employment in the short term. At the same time, the policy response has also tried to incentivise investments in innovation, digital technologies and climate-friendly measures, as illustrated by the European Commission's NextGenerationEU recovery plan. New products, services and processes need to be developed to address the European Union's pressing challenges, such as an ageing population, climate change and numerous environmental and public health issues. Addressing these challenges will create opportunities for firms and jobs for workers. However, for this growth to materialise, governments must create incentives that encourage workers to acquire the new skills necessary to promote innovation.

Innovation is the result of costly and risky processes that require systematic investment in research and experimental development activities. The Frascati Manual (Organisation for Economic Co-operation and Development (OECD), 2015) states that R&D activities must meet five criteria: novel (aimed at new findings), creative (based on original concepts and hypotheses), uncertain (with a high risk of failure), systematic (planned and budgeted) and transferable (or reproducible). For example, the race to find an effective COVID-19 vaccine illustrates the uncertainty associated with innovative activities. It is difficult to predict whether and when the development of new products or services will be achieved. Even when the innovation is successful, expected returns and market success remain highly uncertain and can be volatile (Arrow, 1962). In addition, R&D investment is typically irreversible, regardless of the outcome of the innovation activities, because R&D investments encompass a large share of irrecoverable costs (Pindyck, 1991; Dixit and Pindyck, 1994). R&D investment, and the human capital and knowledge it entails, can be highly project-specific.

Investment in innovation is notoriously difficult to measure. Statistics on R&D expenditure are typically used to compare investment in innovation across countries and firms. However, R&D may only capture a small part of the actual investments in innovation.¹ One way to better capture the innovation activities of firms in advanced economies is to consider investment in other intangible assets, such as software and databases, training of employees and organisational capital (Haskel and Westlake, 2017). Similarly, intellectual property – such as patents for inventions, trademarks, industrial designs, geographical indications and copyright – are complementary to R&D expenditure (Scherer, 1965). Another example of innovation is the application of digital technologies, such as advanced robotics, artificial intelligence, big data and analytics, and the internet of things (Brynjolfsson and McAfee, 2014).

Both the public and private sectors are engaged in innovation, with complementary roles. In most advanced economies, businesses are the largest contributor to R&D expenditure. However, R&D investment by higher education institutions and research institutes is also essential to generating the new knowledge, human capital and skills needed by the private sector. While most business R&D spending is on applied research and experimental development, governments also make major investments in basic science. These investments share the risk associated with innovation and help to attract funds from the private sector (Mazzucato, 2013; Ahmadpoor and Jones, 2017).² For example, a major role played by the public sector is to procure and create demand for innovative products in areas such as cybersecurity, defence and health (Moretti, Steinwender and Van Reenen, 2019). In addition to its direct involvement in R&D activities, the public sector also facilitates the development and use of new ideas, providing supportive conditions for innovative firms.

R&D can suffer from imbalances caused by market failures. An example is when the social returns on R&D are higher than the returns to private firms making the investment. R&D activities are typically affected by several market failures – such as uncertainty, financial constraints and lack of appropriability – that may lead to underinvestment (Nelson, 1959; Arrow, 1962; Stiglitz and Weiss, 1981). For example, the know-how generated by R&D activities could spill over to competitors, preventing the private investors who financed the initial R&D activity from receiving all the returns (Schumpeter, 1942). As a result, public intervention can be justified due to the positive impact R&D spending and innovation can have on the larger society (Griliches, 1992; Hall, Mairesse and Mohnen, 2010; Bloom, Schankerman and Van Reenen, 2013; Jones and Summers, 2020).

Public policy for innovation should go beyond direct support for R&D expenditure. Policies should also consider competition, environmental and trade policies that would help diffuse innovation. Understanding how firms create and adopt innovations is key for the design and implementation of effective public policy. The rising importance of intangible investment and digital technologies means that public policy should not only focus on highly innovative firms in manufacturing or on tax incentives for business R&D investment, but should also improve competition, environmental, data, trade and patent regulations (Furman, Porter and Stern, 2002; Aghion et al., 2005; Bloom, Van Reenen and Williams, 2019).

¹ For example, some large US companies, such as Goldman Sachs and Walmart, report zero R&D in their corporate accounts (Jones, 2016). In addition, accounting and fiscal regulations in many EU countries did not require companies to report R&D expenditure until recently, even for publicly listed firms.

² There are three broad types of R&D activities defined in the Frascati Manual (OECD, 2015): basic research, applied research and experimental development. Basic and applied research are based on experimental or theoretical work undertaken to acquire new knowledge. Unlike applied research, basic research is not directed towards any particular application or use. Experimental development is directed towards producing new products or processes and to improving existing ones. However, basic research does not necessarily lead to applied research and then to experimental development. Experimental development can support basic research with new findings, and basic research can also lead directly to new products or processes (OECD, 2015).

While different policies supporting innovation are often considered and assessed separately, it is vital to recognise that different policy interventions can complement one another (David, Hall and Toole, 2000; Czarnitzki and Delanote, 2015). Finding the right mix is especially relevant for firms that are not at the forefront of technology, as the COVID-19 crisis is likely to exacerbate the digital divide among companies.

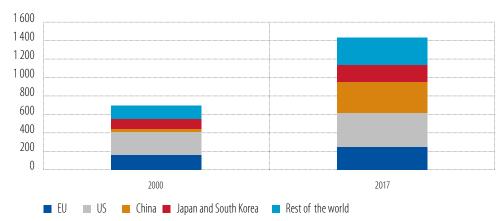
A changing global innovation landscape

Global R&D expenditure has increased rapidly over the past two decades. R&D expenditure reached an estimated EUR 1.4 trillion in 2017, up from EUR 695 billion in 2000 (Figure 1), with China contributing the most to the rise (National Science Board, 2020). From 2000 to 2017, R&D expenditure in China increased tenfold, corresponding to an annual growth rate adjusted for inflation of 16%. In comparison, the yearly increase of domestic R&D expenditure was a modest 2% in the United States and 3% in the European Union.

Figure 1

R&D expenditure in 2000 and 2017

(in EUR billion in purchasing power parity at 2010 prices and exchange rates)



Source: EIB calculations based on European Commission (2020) and Joint OECD-Eurostat international data collection on resources devoted to R&D.

The United States spends the most on R&D, followed by the European Union and China. In 2018, the United States spent more than EUR 492 billion (in current prices) on R&D, followed by the European Union (EUR 295 billion) and China (EUR 252 billion). The relative weight of the United States and the European Union in global R&D expenditure has fallen over time, mainly due to the rapid rise of China. Global R&D performance remains concentrated in three geographic regions: North America, Europe and East Asia.

China has become a leader in innovation. The growing importance of China is also reflected in measures of innovation other than R&D spending, including the stock of international patents related to digital technologies such as artificial intelligence, machine learning, robotics, biotechnology and new materials (OECD, 2019).³ Over the past decade, China has also increased its contribution to highly cited scientific research and its share of the world's top 1% most-cited publications, which rose from less than 2% in 2000 to 18% in 2016 (European Commission, 2020). China falls only behind the European Union and the United States for top-cited publications.

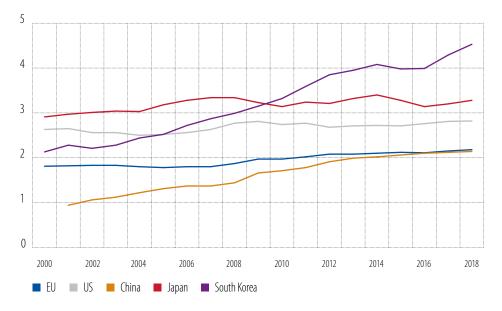
Note: GERD (gross domestic expenditure on R&D), in EUR million expressed as purchasing power parity at 2010 prices and exchange rates.

³ See Chapter 8 of this report, which shows the rapid increase in patenting activities by Chinese firms, especially for digital technologies.

As a share of GDP, the European Union and China are investing less in R&D than the United States. Over the past 15 years, China and South Korea have increased their R&D investment intensity (R&D expenditure as a percentage of GDP), while the United States, the European Union and Japan have been less dynamic (Figure 2). South Korea has the highest R&D intensity among major economies, at 4.5% of GDP in 2018, after overtaking Japan in 2010 and Finland in 2012. With an R&D intensity of 2.14% of GDP in 2018, China is catching up with the European Union (2.18% of GDP).⁴ The European Union has been investing less in R&D as a share of GDP than the United States, Japan and South Korea over the past two decades, a trend that may negatively affect innovation and long-term growth. If policy measures are not taken to support R&D, some highly innovative EU firms may lose their comparative advantage. Lagging EU companies may also find it difficult to catch up and adopt technologies developed elsewhere.

Figure 2

R&D investment intensity 2000-2018 (in %)



Source: Eurostat.

The share of total R&D investment undertaken by businesses is lower in the European Union than in the United States or China. Total R&D expenditure can be broken down by sector: business, government, higher education and private non-profit institutions (including charities). The share of business R&D as a total of R&D expenditure is lower in the European Union (at 67%) than in the United States (73%), or China, Japan and South Korea (78% to 80%). The private sector is driving the rapid increase in R&D expenditure in China and South Korea (Figure 3). However, even if most R&D is undertaken by businesses, the governments in these countries are still actively supporting business R&D. For example, in China, many large companies are directly and indirectly controlled by the state (Veugelers, 2013).

Note: GERD (gross domestic expenditure on R&D) as a percentage of GDP. China excluding Hong Kong. No data for China in 2000.

⁴ The R&D intensity of the United Kingdom is lower than that of the European Union. As a result, the R&D intensity of the European Union is higher when the United Kingdom is removed from EU figures.

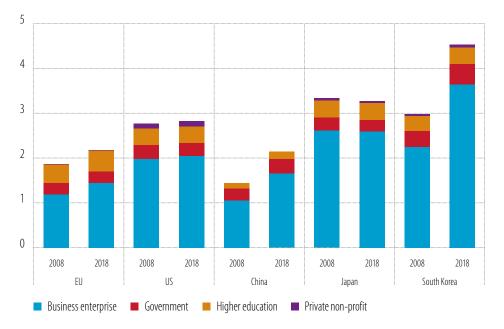


Figure 3 Composition of R&D expenditures in 2006 and 2018 (in % of GDP)

Source: Eurostat.

Note: GERD (gross domestic expenditure on R&D) as a percentage of GDP. China excluding Hong Kong. No data on the private non-profit sector in China.

It remains to be seen whether the sharp contraction in global economic activity in 2020 will lower R&D investment. It is too early to assess the short and long-term impacts of the COVID-19 crisis on R&D and innovation. Major disasters typically compromise incentives to invest in R&D by increasing business costs and causing wide-scale institutional dysfunction (World Bank, 2020). For example, most R&D projects not related to COVID-19 – including important clinical trials – were put on hold, as many universities, research institutes and private companies had to shut down and researchers cut working hours during the first half of 2020 (Cornell University, INSEAD and WIPO, 2020). The strong decline in economic activity following the pandemic may therefore also hit R&D expenditure, especially in the private sector, in 2020.

R&D spending in Europe is too low to meet the Europe 2020 target, which calls for spending equivalent to 3% of GDP. The annual R&D investment gap in the European Union is estimated to be EUR 109 billion. R&D is one of the five headline targets of the Europe 2020 strategy, together with employment, climate change and energy, education, and poverty and social exclusion. By 2020, the European Union was aiming for overall R&D intensity of 3% (and 2% of GDP for business R&D expenditure) through different national targets. Gross domestic spending on R&D in the European Union was EUR 295 billion in 2018, equal to 2.19% of GDP (the most recent figures available). Actual spending in R&D falls short of the target by 0.81 percentage points, equivalent to about EUR 109 billion in 2018. Similarly, R&D expenditure by businesses reached EUR 196 billion (1.45% of GDP) in 2018. Spending fell short of the target of 2% of GDP by 0.55 percentage points, equal to about EUR 74 billion. The R&D investment gap in the European Union remains significant, especially in the business sector.

The rise of software and internet firms among the top global R&D companies

R&D investment is highly concentrated, with a small number of companies, sectors and countries accounting for a large share of business R&D expenditure. For example, the world's top 2 500 R&D companies account for close to 90% of business R&D expenditure, and the top 50 firms account for 40% (Hernández et al., 2020).⁵ R&D concentration is particularly pronounced in high-tech sectors such as software and computer services, pharmaceuticals and biotechnology, and manufacture of technology hardware, but also in traditional industries such as the automotive sector.⁶ Compared to sales or employment, R&D investment is more concentrated among a small number of incumbent firms that have grown bigger over time.

The global R&D landscape changed rapidly over the past decade as the digital economy increased in importance. With more than EUR 18.3 billion spent in 2018, Alphabet (the parent company of Google) was the top global R&D spender, followed by Samsung and Microsoft (Figure 4). The list of the ten largest R&D investors is dominated by US and Asian companies selling software and computer services (Alphabet and Microsoft) or producing electronic and hardware technology equipment (Samsung, Huawei, Intel and Apple). The only EU companies in the top ten are two German car manufacturers (Volkswagen and Daimler). Two pharmaceutical companies (Roche and Johnson & Johnson) are also in the top ten. The top 25 companies include six additional firms in the automotive industry (from Japan, the United States, Switzerland and France), two US software and internet companies (Facebook and Oracle), and two companies producing hardware (Siemens and Cisco Systems). The European Union is thus relatively well represented in the top 25 with six companies, even though the United States is clearly leading with 13 firms. Sanofi and Siemens are the only two EU companies in the top 25 that are not in the automotive sector.

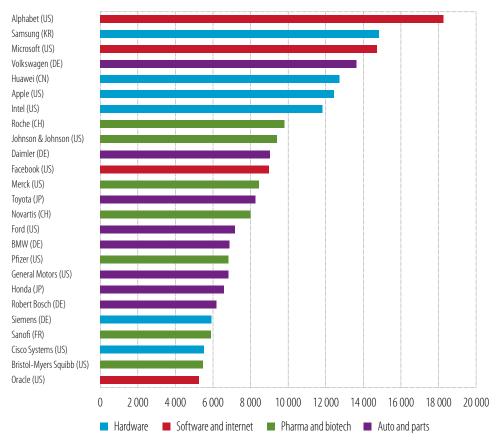
European companies are major global players in R&D and innovation, but the share of EU firms in the top 2 500 R&D investors has fallen over time. The share of firms from the European Union, the United States and Japan on the list of the top 2 500 R&D investors – as well as the share of total R&D investment of these firms – fell from 2006 to 2018 (Figure 5). This fall is largely attributable to the emergence of Chinese firms. While the United States remains an innovation leader, the number of Chinese companies included on the list of big R&D spenders has risen fast – from 0.5% in 2006 to 20% in 2018 – and is now higher than the number of EU companies.

The European Union generates fewer new R&D leaders than China or the United States. China and the United States have a higher number of recent entrants into the list of global innovators – firms that are "new to the club" and not among the top 2 500 global innovators before 2016 – than the European Union and Japan. China has generated 39% of new entrants since 2016, while the United States is responsible for 32% and the European Union only generated 10%. For the United States, the high number of new firms added to the top 2 500 R&D companies was balanced out by firms leaving the list. Otherwise, the number of US firms in the list would presumably have increased over time.

⁵ The world's top 2 500 R&D companies included in the 2019 EU Industrial R&D Investment Scoreboard invested EUR 823 billion in R&D in 2018.

⁶ Eurostat classifies motor vehicle manufacturing as a medium-high-tech sector, whereas pharmaceuticals, computer, electronic and optical products, as well as computer programming and related activities are considered to be high-tech sectors.

Figure 4 R&D expenditure by the top 25 global R&D investors in 2018 (in EUR million)



Source: EU Industrial R&D Investment Scoreboard.

Note:

The companies are ranked based on their R&D expenditure in 2018. Hardware: electronic and electrical equipment, technology hardware and equipment. Software and internet: software and computer services. Pharma and biotech: pharmaceuticals and biotechnology. Auto and parts: automobiles and parts.

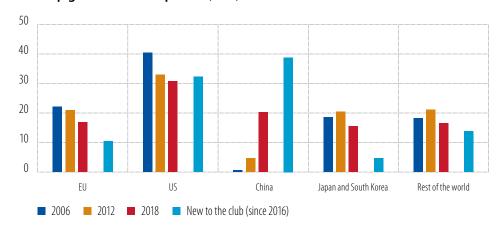
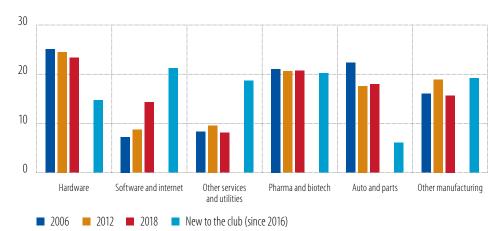


Figure 5 Share of top global R&D companies (in %)

Source:EIB calculations based on EU Industrial R&D Investment Scoreboard.Note:Share of the total number of firms in the list of the top R&D investors, by country. "New to the club" refers to firms that
entered the list of top global R&D investors after 2015.

Companies producing hardware represent almost a quarter of total R&D expenditure, while companies selling software are growing fast and generate more than a fifth of new R&D leaders. Electronic equipment and hardware represent 23% of total R&D spending by the top 2 500 companies, followed by pharmaceuticals and biotechnology, which account for 21% (Figure 6). R&D spending by companies selling software and computer services has increased rapidly over the past decade, with their share rising from 7% in 2006 to 14% in 2018.⁷ In addition, R&D expenditure by companies that are "new to the club" is largest among software and internet firms, followed by pharmaceuticals and biotechnology, and other manufacturing (manufacturing other than automobiles).⁸ The automotive industry remains a solid R&D spender but does not generate many new leaders. For example, a recent entrant to this sector is the US company Tesla, which was founded in 2003 and started car production in 2008.

Figure 6



Share of R&D expenditure 2006-2018 (in %)

Source: EIB calculations based on EU Industrial R&D Investment Scoreboard.

Note: Share of R&D expenditure by the top R&D investors, by sector. "New to the club" refers to firms that entered the list of top global R&D investors after 2015. Hardware: electronic & electrical equipment, technology hardware and equipment. Software and internet: software and computer services. Other services and utilities: fixed line telecommunications, mobile telecommunications, food and drug retailers, general retailers, industrial transportation, travel and leisure, media, banks, equity investment instruments, life insurance, non-equity investment instruments, non-life insurance, real estate investment and services, support services, alternative energy, electricity, gas, water and multi-utilities, industrial metals and mining, oil and gas producers, oil equipment, services and distribution. Pharma and biotech: pharmaceuticals and biotechnology; healthcare equipment and services. Auto and parts: aerospace and defence, automobile and parts. Other manufacturing: beverages, food producers, tobacco, chemicals, construction and materials, forestry and paper, general industrials, industrial engineering, household goods and home construction, leisure goods, personal goods.

The European Union specialises less in software and computer services than the United States and China. The European Union only represents 7% of R&D expenditure among the leading companies in software and computer services, compared with 71% for the United States, 14% for China, and 3% for Japan and South Korea (Figure 7). Similarly, the European Union accounts for 13% of R&D expenditure among leading companies producing technology hardware and electronic equipment, compared with 42% for the United States, 21% for Japan and South Korea, and 15% for China.

⁷ The growth in venture capital investment during this period was also largely driven by investment in software and computer services (Cornell University, INSEAD and WIPO, 2020).

⁸ Alphabet, the largest R&D spender according to the 2019 EU Industrial Scoreboard, was created through a restructuring of Google in October 2015. It is included in the software and internet sector but not in the "new to the club (since 2016)" category.

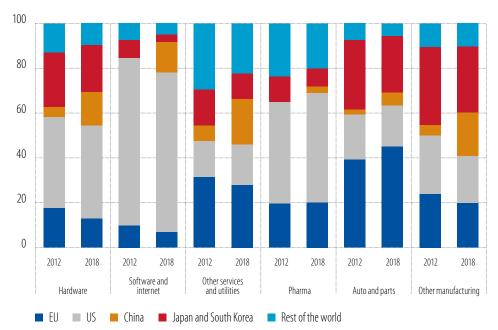


Figure 7 Share of R&D expenditure in 2012 and 2018 (in %)

Source:EIB calculations based on EU Industrial R&D Investment Scoreboard.Note:Share of R&D expenditure by the top R&D investors, by sector and country. See note to Figure 6 for a detailed list of
industries.

The difference in business conditions and the regulatory environment may explain the gap between the European Union and the United States in creating new leading innovators. Business conditions in the European Union and the United States differ, including access to finance and the regulatory environment. The European Union's regulatory environment may not sufficiently support young European firms undertaking risky and innovative investments (European Commission, 2018). For instance, the venture capital market is smaller in Europe than in the United States or Asia – where it has grown rapidly in recent years, especially in China.⁹ The European Union does not appear to be generating many new innovation leaders, especially in fast-growing sectors such as software and computer services. This may jeopardise Europe's long-term competitiveness.

Europe's weaknesses could lead to the emergence of future tech champions in other regions of the world, where companies developing new technologies are better supported by the existing digital infrastructure, including hardware, software and digital services. The COVID-19 crisis has highlighted the need for EU firms to aggressively invest in digital technologies. Substantial investments are needed to improve information and communications technology (ICT) infrastructure and increase the digital skills of the workforce. A weak digital sector means that EU companies and citizens will lack ownership of their data, leaving the data to be controlled outside the European Union – as illustrated by the discussion in various countries on whether to use equipment provided by the Chinese company Huawei in new 5G telecommunication networks.

Europe has strong traditional industrial sectors that were not born digital. Many indicators suggest Europe is falling behind in the digital transformation at a time when industry 4.0, the use of automation

⁹ Venture capital in the United States, Asia and Europe declined sharply in the first quarter of 2020. This is expected to affect young and small firms in particular. At the same time, recent venture capital deals financing innovation seem to have been redirected towards health, online education, big data, e-commerce and robotics (Cornell University, INSEAD and WIPO, 2020).

and data in manufacturing, is gaining momentum and has started to substantially change the business models of traditional industries (EIB, 2019). Digitalisation pervades the global economy and is arguably one of the most important drivers of firms' innovation, competitiveness and growth (Rückert, Veugelers and Weiss, 2020). The digital transformation of traditional industries and the development and adoption of new technologies in the European Union require large investments in R&D and innovation.

The pharmaceuticals and biotechnology sector is dominated by US companies, which account for almost half of the R&D spending of the sector's top companies. Nevertheless, EU companies continue to be important players, accounting for 20% of global R&D investment in this sector (Veugelers, 2013). Most R&D investment in pharmaceuticals and biotechnology is concentrated in a handful of champions: the top ten firms make up half of R&D expenditure.¹⁰ However, even in this sector, the share of R&D expenditure from Chinese companies has increased rapidly over time. The pandemic has renewed the focus on R&D in the health sector, which is likely to grow strongly in the short and medium term. Box A discusses the EU response to accelerate the search for COVID-19 vaccines, including support for health-related R&D efforts. The sector is also adopting digital technologies rapidly as they allow for faster and more precise diagnosis of diseases. That faster diagnosis enables treatments to start earlier, which can improve patients' health and save lives.

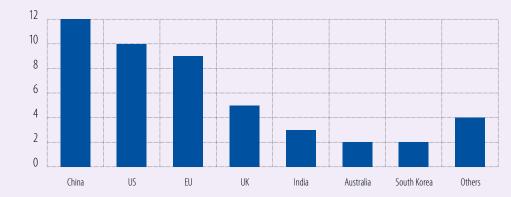
10 The large share of R&D expenditure in pharmaceuticals and biotechnology attributed to the rest of the world is driven by two Swiss pharmaceutical companies (Roche and Novartis).

Box A

The European strategy in the search for COVID-19 vaccines

The global crisis caused by the pandemic spurred a healthcare development race that is unprecedented in scale and pace. In the ten months following the discovery of the pathogen, global research efforts have rapidly expanded. As of October 2020, those efforts encompassed more than 190 candidate vaccines, including 40 in clinical trials on humans (Figure A.1). Additionally, many health sector companies have shifted their focus to delivering tests and therapeutics for COVID-19. In parallel to investing in R&D, countries must also rapidly scale up manufacturing capacity, secure procurement agreements and ensure prompt delivery of the vaccine.

Figure A.1



Number of developers of vaccines in clinical trials as of October 2020

Source: World Health Organisation. Note: Partnerships between intern

Partnerships between international firms count as multiple countries. For example, Sanofi-GSK is developing one vaccine, but it is a partnership between a French and British firm, and therefore counts as one for the European Union and one for United Kingdom. "Others:" Cuba, Japan, Kazakhstan, and Singapore – where one vaccine is being developed in each country. In this challenging landscape, European institutions have made a substantial effort to support EU companies' R&D, while also improving the regulatory framework and helping firms to increase manufacturing capacity. The European Union approached all funding projects from a technology-neutral perspective, supporting a wide range of competing innovation processes and research on various vaccines. The European Commission has already invested EUR 459 million from its Horizon 2020 research and innovation programme in more than 100 projects tackling the consequences of the health crisis. These projects include the development of diagnostics, treatments, and vaccines, as well as the creation of infrastructure and data resources needed for research.

The EIB has provided debt financing to support the research and development of the most promising COVID-19-related projects. For example, it provided EUR 100 million in financing for the German company BioNTech to support its BNT162 vaccine programme, as well as EUR 75 million for CureVac and its CVnCoV vaccine. BioNTech, which received EIB funding, developed the first vaccine approved in the United States, the United Kingdom and the European Union. The company also had the third-largest manufacturing capacity of potential vaccine makers, with an estimated 1.3 billion doses ready to be produced by the end of 2021.

The European Commission has also started contracting advance purchase agreements with manufacturers. These agreements specify that, in return for the right to buy a specified number of vaccine doses in a given time frame, the Commission agrees to finance part of the upfront costs faced by vaccine producers. As of October 2020, the Commission had signed contracts with British-Swedish firm AstraZeneca and British-French company Sanofi-GSK, and had held exploratory talks with Johnson & Johnson, CureVac, Moderna and BioNTech.

As of September 2020, EU members and other EU agencies had provided EUR 786 million in R&D funding, which corresponds to about 0.005% of EU GDP (Figure A.2). The United States is the only country that has provided more R&D funding for COVID-19 vaccines than the European Union – on the back of a USD 2 billion grant provided to the US Biomedical Advanced Research and Development Authority (BARDA). The United States has also provided the highest level of R&D funding as a percentage of GDP, followed by South Korea, the United Kingdom and the European Union.

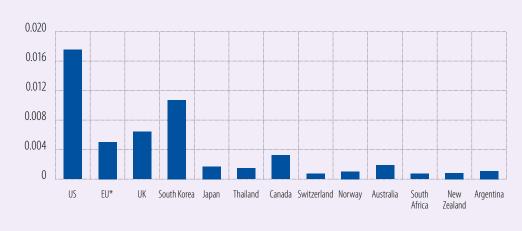
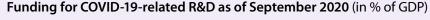


Figure A.2



Source: EIB calculations based on R&D data from the OECD Global Science Forum (GSF) Research Funding Initiative, 2019 GDP data from the OECD.

Note: EU* includes funding by Member States and EU agencies. Countries are ranked based on total R&D funding (in USD) as of September 2020. In some cases, R&D funding has been announced but without indicating the amount. That funding is therefore not included in the figures.

Once a candidate vaccine is approved, it is critical that manufacturing and distribution capacities are ready to supply a significant number of doses. Even prioritising the most at-risk population worldwide (healthcare workforce, frail and elderly, patients with co-morbidities, etc.), a vaccine requiring two doses to be administered would equal 3.6 billion doses globally. It is therefore crucial that EU capacity be sufficient to ensure adequate immunisation campaigns for its Member States and other countries in the medium to long term.

To cope with these capacity requirements, the European Union's strategy has been to expand production and logistics facilities. The funding initiatives discussed above will also help scale up manufacturing capacity in Europe. In addition, in late September 2020 the European Commission and EIB jointly pledged to invest EUR 400 million in the COVAX facility, an international platform for the development and manufacturing of COVID-19 vaccine candidates. All COVAX participating countries (approximately 170 countries as of October 2020) will have equal access to these vaccines, regardless of their level of contribution to the financing of the platform. The initiative will enable residents of low and middle-income countries to access COVID-19 vaccines once developed.

Europe remains a global leader in R&D investment in the automotive industry. Global R&D expenditure by companies in aerospace, defence and automobiles is heavily concentrated in a few European countries, Japan and South Korea, with these countries accounting for about 70% of total R&D spending. The US share has fallen over time, while the presence of China is becoming more evident, particularly as the country develops electric vehicles (EIB, 2019).¹¹ The automotive sector is being transformed by the need to develop engines that are not reliant on fossil fuels, as well as the increased use of digital technologies and new trends such as electric vehicles, autonomous driving and car sharing. If EU firms are not able to better integrate digital technologies into their business models, they risk becoming less relevant, even in sectors where they currently lead. Laying the foundation for the rapid digitalisation of this sector is crucial, and the European Union can benefit from its leading position in climate action (see Chapter 8 for further discussion).

Although it is difficult to predict how business R&D spending will react to the current crisis, experience from the financial and sovereign debt crisis shows that R&D investment and sales for leading EU and US companies can recover rapidly. At the same time, the rebound in the number of workers employed by the top 500 and R&D investors in the European Union and United States was more modest, especially in the European Union (Figure 8). It is difficult to predict whether similar patterns will be observed after the COVID-19 crisis. The top EU companies appear to be less dynamic than their US peers. At the same time, robust growth among US companies (especially in the number of employees) could also reflect their rising market concentration in digital sectors, where economies of scale and winner-takes-all dynamics are very important (Calligaris, Criscuolo and Marcolin, 2018).

¹¹ About 47% of the 7.2 million electric cars sold from 2010 to 2019 were in China (International Energy Agency (IEA), 2020). In addition, close to 98% of the 500 000 electric buses in operation globally have been deployed in Chinese cities. China also continues to lead in the rollout of publicly accessible electric chargers, especially fast chargers.

Figure 8

Median annual growth of sales, R&D expenditure and number of employees among the top 500 R&D companies in the European Union and United States (in %)



Source: EIB calculations based on EU Industrial R&D Investment Scoreboard.

Note: Median annual growth rate of sales, R&D expenditure and the number of employees (in %) among the top 500 EU and US companies that already existed in 2005.

Box B Towards a sustainable ICT sector?

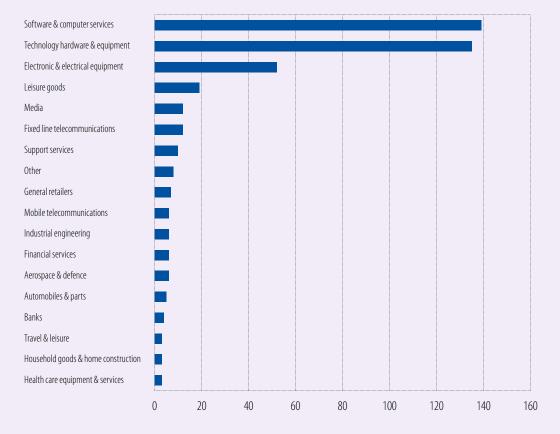
Formulating policies that promote sustainability and the reduction of global greenhouse gas emissions is necessary to address climate change. The ICT sector is responsible for a significant amount of greenhouse gas emissions and, at current trends, could turn into one of the largest global contributors. However, by fostering the development of green technologies, the ICT industry could also prove essential to transitioning to a green economy. To assess the current contribution of the sector to green development, the analysis described in this box breaks down the R&D output of global ICT leaders into green and non-green patents. The results suggest that a significant portion of the investment made by leading ICT firms contributes to climate change mitigation and adaptation.

The ICT industry is estimated to consume 6% to 10% of global electricity and to contribute 3% to 9% of greenhouse gas emissions (Andrae and Edler, 2015; Belkhir and Elmeligi, 2018; Malmodin and Lundén, 2018). While these figures may overestimate the actual ICT footprint (Malmodin and Lundén, 2016; Shehabi et al., 2016), the ICT sector is large, growing, and its impact on society is pervasive.

ICT industry's ability to produce a sustainable model depend on the balance struck between the increasing demand for ICT services and devices and the sector's ability to increase its energy efficiency, including the use of efficient technologies. Many players are active in the development and adoption of sustainable ICT (or "green IT", as labelled by Herzog, Lefèvre and Pierson, 2015): "They span from individual persons (e.g., an activist, a researcher, a consultant), research groups in academia (research institutes, universities, academic research networks), companies (developing technologies, advising companies), groups of companies (influential and lobbying groups), governments (through public incentives, laws), to groups of governments (e.g., European Union)."

This box focuses on one type of player: large companies that invest in R&D. Their size and position in the industry allow them to significantly influence the development of green technology. Large incumbent tech giants are more able to react and support green ICT development. Data on the largest global ICT-related companies (such as Hewlett-Packard, IBM, Cisco, etc.) from the EU Industrial R&D Investment Scoreboard are used to analyse trends in the development of new technologies and patenting activities in green IT.

Figure B.1 Number of ICT-specialised companies, by sector



Source: The 2017 EU Industrial R&D Investment Scoreboard, European Commission, Joint Research Centre (JRC) / Directorate General for Research and Innovation (DG RTD).

The selection of leading ICT companies is not limited to the sectoral classification, but rather to the ICT taxonomy based on International Patent Classification patent families¹² (Daiko et al., 2017) grouped into 12 broad categories.¹³ Companies are defined as technologically specialised in ICT when they are predominantly active in the development of IP5 patent families pertinent to these ICT categories.¹⁴ The

¹² The patent families in this analysis are fractionally counted according to their year of worldwide first filing, commonly known as the priority year, which is closest to the date of invention. Patent assignee data from PATSTAT are matched with data from EU Industrial R&D Investment Scoreboard at the level of individual companies (including subsidiaries where available) using a series of probabilistic string-matching algorithms.

¹³ The 12 categories are: high speed networks, mobile communication, security, sensor and device networks, high-speed computing, large-capacity and highspeed storage, large-capacity information analysis, cognition and meaning understanding, human-interface, imaging and sound technology, information communication devices, electronic measurement, and others.

¹⁴ IP5 is the name given to a forum of the five largest intellectual property offices in the world: the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the National Intellectual Property Administration of the People's Republic of China (CNIPA), and the United States Patent and Trademark Office (USPTO).

technological specialisation of top R&D investors is derived from revealed technological advantage (RTA) indicators, compiled at the company level.

The RTA index is defined as the share of a firm's patents that are pertinent to a particular technology divided by the share of patents from all firms in that technology.¹⁵ The index is equal to 0 when the company has no patents in an ICT-related technology. It takes a value of between 0 and 1 when the company does not specialise in ICT per se, and it is larger than 1 when it is relatively specialised in ICT technologies.

Among the 1 824 Investment Scoreboard firms with IP5 families in from 2007 to 2018, 436 companies had an RTA in ICT-related technologies larger than 1. Figure B.1 reports the number of firms that are technologically specialised in ICT, by their original sector classifications. While the majority of ICT-specialised firms belong to classical ICT sectors (such as software and computer services, technology hardware and equipment), the list also includes firms in industrial engineering, aerospace and defence, automobile and parts or banks, which are not ICT companies but are specialised in ICT technologies.

Top R&D investors worldwide play a leading role in the development of ICT-related technologies. Together they own about 75% of world IP5 patent families in ICT technologies (Daiko et al., 2017). The 436 ICT-specialised companies represented 34% of the total R&D spending of the top 2 000 R&D investors worldwide in 2016. The majority of these ICT companies are located in the United States, representing half of R&D spending and 40% of net sales of the ICT sample.

To measure ICT companies' efforts in developing green technologies, green patent families have been identified based on the Cooperative Patent Classification (CPC) classification scheme. More specifically a patent is classified as green if it contains CPC codes that belong in the Y02 and/or Y04 subclasses. Among the 436 ICT-specialised companies, 270 firms are also active in filing green patents and, among those, 44 firms are "intensively green" (highly patenting in green technologies, with a green RTA higher than 1). The analysis also identifies 4 136 patent families, which are classified as pertinent to both ICT and green technologies at the same time.

The majority of the R&D investment is done by ICT companies that also patent in green technologies (Figure B.2). Half of the "intensively green" ICT companies are located in the United States (22 of 44 firms). About 20%-25% of the patents of ICT companies are in green technologies (Figure B.3). ICT companies from Japan and South Korea (included in rest of the world) have been outperforming companies in other regions for the past decade. The overall share of green patents has been decreasing since 2012, potentially due to the lag between the first filing date and the patent issuance date. Chinese ICT companies are alone in having increased their share of green patents, reaching and sometimes surpassing the levels of European ICT companies in 2012. The main green technologies developed by ICT include: ICT energy reduction and technologies aiming at reducing greenhouse gas emissions (Figure B.4).

¹⁵ The RTA is a ratio of two shares: the share of patents in tech T by firm j over the patents of all firms in the same tech T.

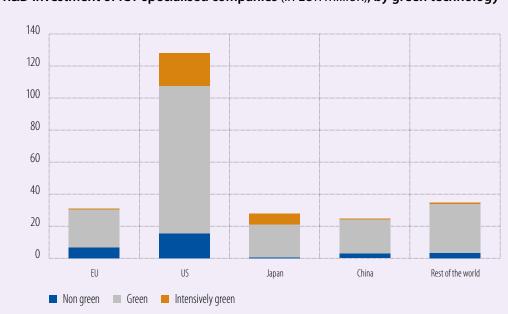


Figure B.2 R&D investment of ICT-specialised companies (in EUR million), by green technology

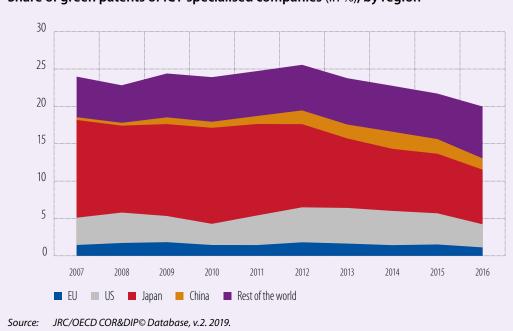


Figure B.3 Share of green patents of ICT-specialised companies (in %), by region

Source: The 2017 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

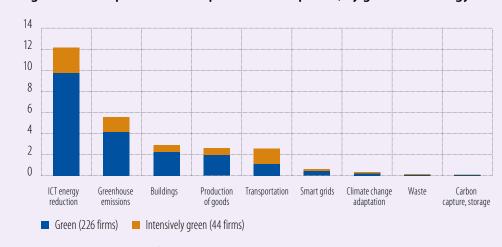
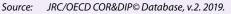


Figure B.4 Average number of patents of ICT-specialised companies, by green technology



Policymakers are placing ICT at the centre of their environmental strategies to monitor climate change and to facilitate the transition towards a green and circular economy. ICT is therefore an industry critical to ensuring the co-existence of economic growth and the environment. To manage the negative impact that ICT may have on the environment and to harness its potential to achieve sustainable growth, the ICT industry will also need to be more involved in developing regulations and standards. In addition, creating incentives for the private sector to invest in green ICT may help accelerate the development of a market.

Intangible investment in the European Union and the United States

R&D investment is an important component of business performance but other types of intangible assets – including software and data management, employee training and organisational capital – are increasingly important. According to EIBIS data, firms in the European Union and the United States allocated 36% of their total investment to intangibles in 2019: R&D, software and data management, employee training, and organisational and business process improvements (Figure 9). Within the European Union, the share of investment spent on intangibles is lower in Central and Eastern Europe (26%) than in Western and Northern Europe (37%) or Southern Europe (36%). The differences in intangibles registered within the European Union is in line with estimates from macroeconomic statistics on intangible capital (EIB, 2016).

Manufacturing firms tend to invest more in R&D than companies from other sectors, while firms in services allocate a higher share of investment to software and data, IT networks and website activities. Manufacturing firms in the European Union allocated 13% of total investment to R&D and 9% to software and data in 2019 (Figure 10). During the same period, EU firms in services only allocated 4% to R&D but more than 19% to software and data. The pattern for US firms is very similar. Overall, machinery and equipment remains the most important investment area for all firms, even for those in services.

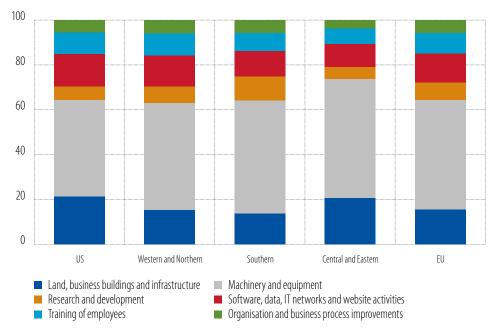


Figure 9 Composition of investment across the European Union and the United States (in %)

Source: EIBIS 2020.

Figure 10

Note: Firms are weighted with value added.

Question: In the previous financial year, how much did your business invest in each of the following with the intention of maintaining or increasing your company's future earnings?

100 80 60 40 20 0 Manufacturing Construction Services Infrastructure Manufacturing Construction Services Infrastructure EU US Land, business buildings and infrastructure Machinery and equipment Research and development Software, data, IT networks and website activities Training of employees Organisation and business process improvements

Composition of investment in the European Union and the United States (in %), by sector

Source: EIBIS 2020.

Note: Firms are weighted with value added.

Question: In the previous financial year, how much did your business invest in each of the following with the intention of maintaining or increasing your company's future earnings?

Firms that invest more in intangible assets tend to be more productive and innovative. They are more likely to develop or introduce new products, processes or services (EIB, 2018). While R&D investment (including the acquisition of intellectual property) is a big factor, investment in software and databases and in organisation and business processes is also important. Complementary intangible assets help spur innovation (Haskel and Westlake, 2017; Brynjolfsson, Rock and Syverson, 2018; Cincera et al., 2019).

The United States has a higher share of active innovators than the European Union. Firms can be classified under five different innovation profiles based on R&D investment and innovation activities (Veugelers et al., 2019). The five innovation profiles are: firms that do not innovate, adopting firms, developers, incremental innovators and leading innovators (Figure 11). The European Union has a higher share of firms that do not invest to develop or introduce new products, processes or services. The European Union also has a lower share of active innovators – the firms that actively invest in R&D (developers, incremental and leading innovators) – than the United States. The difference stems from a lack of incremental innovators in Europe. Incremental innovators are firms that invest in R&D and introduce products, processes or services that are new to the company (but not to their market). Innovation policy in Europe needs to better target firms with the potential to grow, and active innovators tend to grow faster than other firms, are more likely to export their products or services, are more competitive and have higher productivity (EIB, 2018).

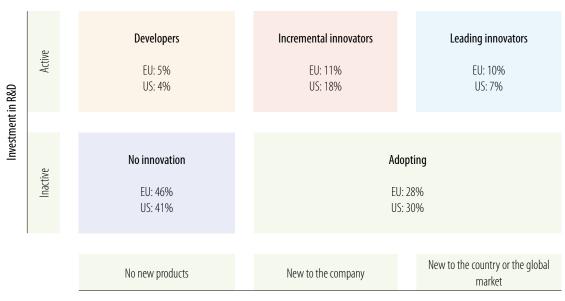


Figure 11 Innovation profiles in the European Union and the United States

Developing or introducing new products, processes or services

Source: EIBIS 2020.

Note: R&D inactive refers to firms with an R&D investment intensity (R&D investment divided by turnover) below 0.1%. Firms are weighted by value added.

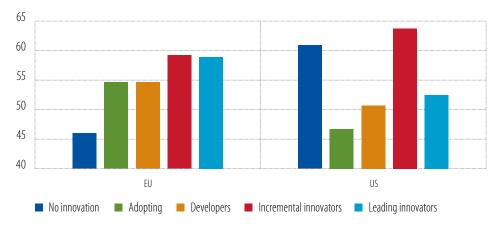
Question: In the previous financial year, how much did your business invest in each of the following with the intention of maintaining or increasing your company's future earnings? What proportion of the total investment in the previous financial year was allocated to developing or introducing new products, processes or services?

More innovative firms tend to report that the pandemic will have a long-term positive impact on the use of digital technologies. The majority of firms in the European Union (52%) and the United States (56%) expect the pandemic to boost digitalisation, for example to prevent business disruption or to improve communication with customers, suppliers and employees. In the European Union, firms' views on the pandemic's impact depend on their innovation profiles. While only 46% of non-innovative

firms expect the use of digital technologies to increase in the long term due to the pandemic, this share increases to 54% for adopters and developers, and to 59% for incremental and leading innovators. The relationship is less clear-cut for the United States, where a large share of firms that do not innovate also expect COVID-19 to boost digitalisation.

Figure 12

Share of firms that expect the pandemic to have a long-term impact on the use of digital technologies in the European Union and the United States (in %), by innovation profile



Source: EIBIS 2020.

Note: See Figure 11 for a definition of innovation profiles. Firms are weighted with value added.

Question: Do you expect the coronavirus outbreak to have a long-term impact on the increased use of digital technologies (in order to prevent business discontinuity or improve communication with customers, suppliers and employees)?

Adoption of digital technologies in the European Union and the United States

The COVID-19 crisis has led to wider recognition of the importance of innovation and digital transformation. Until recently, the implementation of digital technologies was considered an important contributor to market success and usually associated with the most innovative and modern companies. The pandemic, however, has made the digital transformation an integral part of many firms' survival. Digitalisation is indispensable to preventing business disruption, organising work remotely, improving communication with customers, suppliers and employees, and selling products and services online.

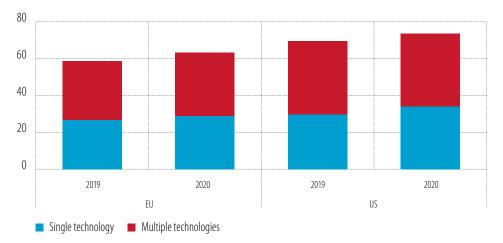
Digital adoption rates are lower for EU firms than US firms. In 2020, 37% of firms in the European Union had not implemented any digital technology, compared to only 27% of firms in the United States (Figure 13). Digital adoption is expanding rapidly among businesses. The share of firms with at least one digital technology has increased compared to EIBIS survey results from last year, both in the European Union and the United States. However, the European Union is not closing its digital gap with the United States.

The majority of firms that are already digital have implemented more than one digital technology. At the same time, about 40% firms report having adopted at least one of the technologies in the past year. Digitalisation therefore appears to be a recent priority for many firms. This suggests that the European Union needs to make efforts to support investment in digitalisation to catch up with US firms.

The difference in digital adoption rates between the European Union and the United States is particularly large in the construction and service sectors. The share of construction firms that are nondigital is 60% in the European Union, compared to only 23% in the United States (Figure 14). The difference in digital adoption rates between EU and US firms is 12 percentage points in services, 6 percentage points in the infrastructure sector and 3 percentage points in manufacturing. In the manufacturing and infrastructure sectors, most firms that are already digital have implemented more than one technology. However, most firms in construction and services – the sectors in which EU firms also have the largest gap with the United States – have only implemented one technology.

Figure 13

Adoption of digital technologies (in %)

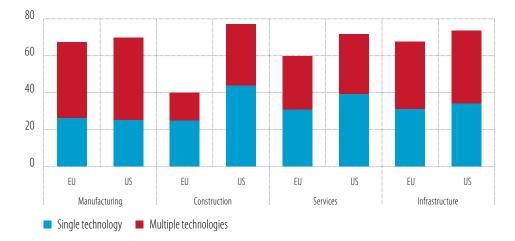


Source: EIBIS 2019 and 2020.

Note: A firm is identified as "digital, single technology" if one digital technology was implemented in parts of the business and/or if the entire business is organised around one digital technology. A firm is identified as "digital, multiple technologies" if at least two digital technologies were implemented in parts of the business and/or if the entire business is organised around at least two digital technologies. Firms are weighted using value added.

Question: Can you tell me for each of the following digital technologies if you have heard about them, not heard about them, implemented them in parts of your business, or whether your entire business is organised around them? Firms are asked to answer the question for four different digital technologies specific to their sector (see the note to Figure 15 for the definition of digital technologies).





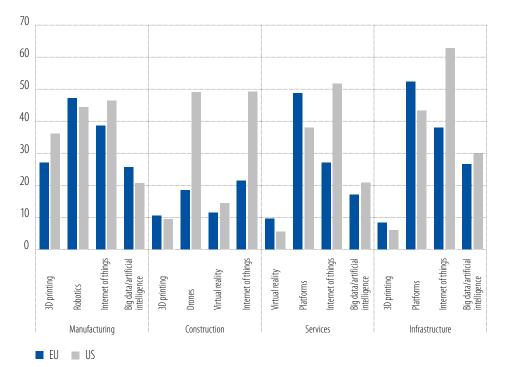
Source: EIBIS 2020.

Note: See note to Figure 13 for the definition of digital adoption. Firms are weighted by value added.

EU firms have lower adoption rates for the internet of things than US firms. Data on specific digital technologies within the four sectors indicate that the adoption rate differences between the European Union and the United States are driven by the lower adoption rates of internet of things technologies, such as electronic devices that communicate with each other without assistance (Figure 15). In addition, US construction firms employ drones more often than firms in the European Union.

Figure 15

Adoption of different digital technologies (in %)



Source: EIBIS 2020.

Note: "3D printing": also known as additive manufacturing; "Robotics": automation via advanced robotics; "Internet of things": refers to electronic devices that communicate with each other without human assistance; "Big data/artificial intelligence": cognitive technologies, such as big data analytics and artificial intelligence; "Drones": unmanned aerial vehicles; "Virtual reality": augmented or virtual reality, such as presenting information integrated with real-world objects presented using a head-mounted display; "Platforms": platform that connects customers with businesses or customers with other customers. Firms are weighted using value added.

Firms in Southern Europe are more likely to have implemented internet of things and platform technologies than in Western and Northern Europe or Central and Eastern Europe. This helps to explain the higher rate of digital adoption in Southern Europe, especially in the construction and infrastructure sectors. At the same time, firms in Western and Northern Europe more often report having adopted 3D printing and cognitive technologies, such as big data analytics and artificial intelligence (Figure 16).

Larger firms have higher rates of digital adoption than smaller firms. In the European Union, only 40% of microfirms (five to nine employees) have implemented at least one digital technology, while 75% of large firms (with more than 250 employees) are already digital (Figure 17). Perhaps unsurprisingly, large firms are also much more likely to have implemented multiple technologies. The difference in digital adoption rates between the European Union and the United States appears to be particularly important for small firms (10 to 49 employees). Zooming in on the four different sectors, the size definitely plays a role for manufacturing firms. For example, only 30% of EU manufacturing firms with fewer than ten employees are digital, whereas 79% of large EU manufacturing firms have implemented digital technologies. However, the size effect is observed in the other sectors as well, both in the European Union and the United States.

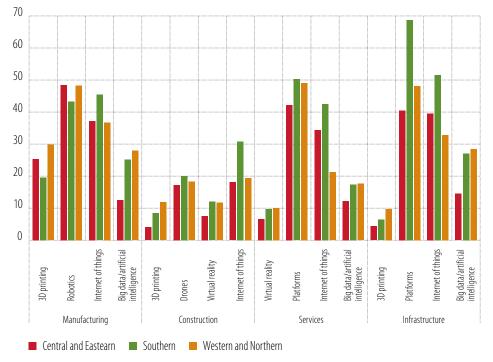


Figure 16 Adoption of different digital technologies across the European Union (in %)

Source: EIBIS 2020. Note: See note to

ote: See note to Figure 15 for the definition of the digital technologies. Firms are weighted by value added.

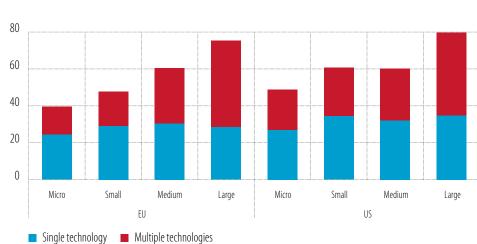


Figure 17 Adoption of digital technologies (in %), by firm size

Source: EIBIS 2020.

Note:

See note to Figure 13 for the definition of digital adoption. Firms are weighted by value added.

Firm size and market segmentation are holding back European firms' digital adoption. EU firms are, on average, smaller than US firms. Investment in digital technologies often entails high fixed costs, making the adoption (of one or multiple technologies) easier for larger firms that can spread the costs over a larger revenue stream. Market fragmentation in the European Union prevents firms from quickly adopting digital technologies, preventing EU firms from closing the gap with their US peers.

Digital firms grow faster than firms that have not implemented digital technologies. Digital firms are more likely to have hired new employees over the past three years, both in the European Union and the United States, while a larger share of non-digital firms are stagnating (Figure 18). This indicates that firms moving ahead with digitalisation – in particular, firms that have already implemented multiple technologies – are more dynamic than firms that do not invest in digitalisation and are left behind (Rückert, Veugelers and Weiss, 2020). Looking ahead, firms that have implemented multiple technologies often expect digitalisation to increase the number of employees in their business over the next three years.¹⁶

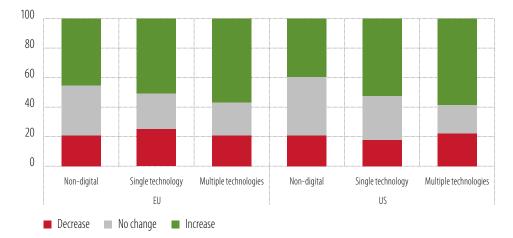


Figure 18 Employment growth over the past three years (in %), by digital intensity

Source: EIBIS 2020.

Note: See note to Figure 13 for the definition of digital adoption. Firms are weighted using weighted by value added. Questions: How many people does your company employ either full or part-time at all its locations, including yourself? How many people did your company employ either full or part-time at all its locations, three years ago?

Digital firms tend to implement better management practices than non-digital firms. Digital firms use formal strategic business monitoring systems (with key performance indicators) more often than non-digital companies, both in the European Union and the United States (Figure 19). The effect is even larger for firms that have implemented multiple digital technologies. Digital companies also tend to reward individual performance with higher pay. In addition, they are more likely to have appointed a designated person responsible for defining and monitoring climate change strategies. Those firms report more frequently that they have set and are monitoring targets on carbon emissions and energy consumption.¹⁷ This EIBIS-based evidence is in line with results from previous studies highlighting the importance of management practices for technology adoption and firm performance (Bloom et al., 2019). The European Union and its Member States need to create incentives for firms to improve their track record on environmental, social and corporate governance (ESG) metrics – an area where digital technologies may help firms monitor progress.

¹⁶ See also the discussion on digitalisation and skills in Chapter 10 of this report.

¹⁷ The positive associations between digital intensity and management practices also hold in regression analysis that controls for firm size as well as country and sector. In other words, this association is not driven by a firm size effect.

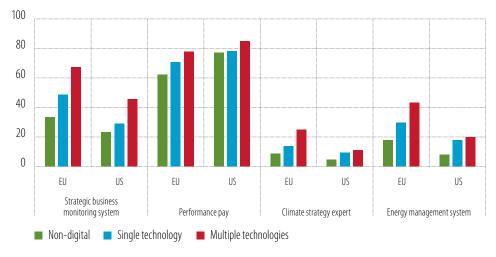


Figure 19 Management practices (in %), by digital intensity

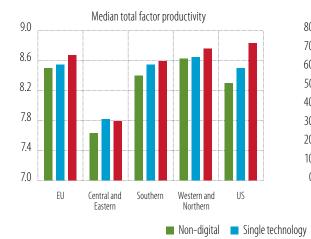
Source: EIBIS 2020.

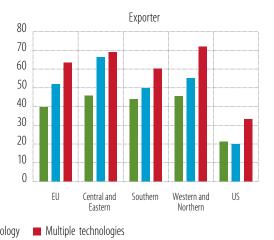
Note: See note to Figure 13 for the definition of digital adoption. Firms are weighted using value added.

Question: In 2019 and under normal conditions, did your company use a formal strategic business monitoring system; reward individual performance with higher pay; have a designated person responsible for defining and monitoring climate change strategies; set and monitor internal targets on carbon emissions and energy consumption?

Figure 20

Total factor productivity (in logarithm), and exporting goods and services to another country (in %), by digital intensity





Source: EIBIS 2020.

Note: See note to Figure 13 for the definition of digital adoption. Total factor productivity (TFP) is computed as the residual from ordinary least squares (OLS) regressions with value added as the dependent variable, and the value of fixed assets and the number of employees as explanatory variables. The regressions are estimated separately for different sectors, controlling for the interactions of country and year fixed effects. The figure (left panel) shows the median TFP for different categories. Firms are weighted weighted by value added.

Question (right panel): In the previous financial year, has your company directly exported goods and services to another country?

Digital firms tend to be more productive and are more likely to export their products and services. Digital firms, especially firms that have implemented multiple digital technologies, have higher median labour productivity and higher median total factor productivity than non-digital firms, both in the European Union and in the United States (Figure 20). The effect is particularly pronounced for US firms. These results support previous empirical evidence on the positive effect of digital adoption – including the use of platform technologies in the services sector – on productivity in Europe and the United States (Falk and Hagsten, 2015; Bailin Rivares et al., 2019; Gal et al., 2019). Digital firms are also more likely to directly export goods and services to another country, which is in line with studies stressing that exporters tend to be more productive (Melitz and Redding, 2015).¹⁸ Investing in digital technologies therefore appears to be especially relevant to these firms if they want to be able to compete in international markets.

Digital firms pay higher wages on average. Many economists argue that digital technologies – such as artificial intelligence, machine learning and industrial robots – have an impact on employment, wages, the demand for skills and job polarisation because of automation and skill-biased technological change (Acemoglu and Autor, 2011; Autor, 2015; EIB, 2018; Frank et al., 2019; Acemoglu and Restrepo, 2020). Analysis based on the EIBIS shows that firms that have adopted multiple technologies tend to pay higher wages (Figure 21). While digitalisation can disrupt employment and tasks, the jobs created by digital firms often appear to be relatively well paid. Compared to other regions, wages are lower in Central and Eastern Europe and the wage premium for digital firms is weaker. In addition, the distribution of wages tends to be wider for digital firms, especially in the United States, which may support the evidence of wage polarisation in the labour market.

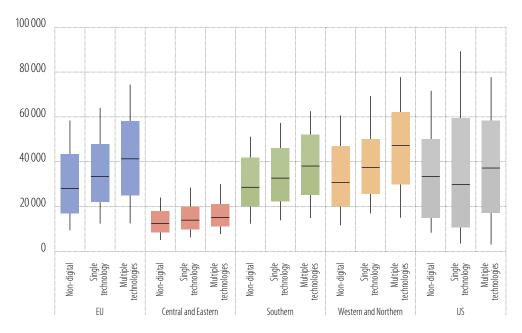


Figure 21

Distribution of average wage per employee (in EUR), by digital intensity

Source: EIBIS 2020.

Note: See note to Figure 13 for the definition of digital adoption. The figure shows the 10th, 25th, 50th, 75th and 90th percentiles of the distribution of the average wage per employee. The average wage per employee is computed as the wage bill divided by the number of employees. Firms are weighted weighted by value added.

Question: How much did the company spend on wages in the previous financial year?

¹⁸ In regression analysis that controls for firm size, country and sector, both total factor productivity and export status are positively associated with digital intensity.

Digital firms invest more in R&D than firms that are non-digital. The stronger focus on R&D (including the acquisition of intellectual property) is particularly pronounced for firms that have already implemented multiple technologies (Figure 22). In addition, digital firms tend to have higher investment intensity.¹⁹ They also report having increased investment in the past year more often than non-digital firms.

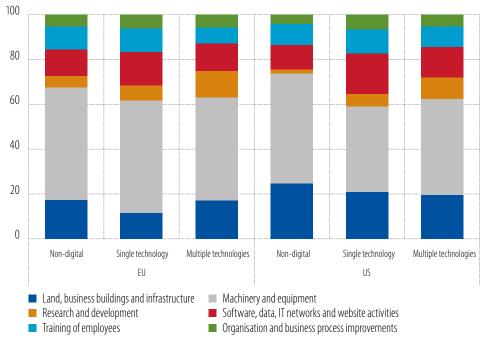


Figure 22

Composition of investment (in %), by digital intensity

Source: EIBIS 2020.

Note: See note to Figure 13 for the definition of digital adoption. Firms are weighted weighted by value added.

Question: In the previous financial year, how much did your business invest in each of the following with the intention of maintaining or increasing your company's future earnings?

Firms that have implemented multiple digital technologies more often engage in innovation activities. The share of active innovators, either incremental innovators or leading innovators (such as firms that invest in R&D and introduce new products, processes and services, see Figure 11), is higher among adopters of multiple digital technologies (Figure 23). At the same time, non-digital firms are more likely to be firms

that do not innovate – as they do not conduct any R&D and do not develop new products, processes or services. Big data analytics and artificial intelligence (AI) appear to be strongly linked to the innovation activities of digital firms. To make the most of these technologies, firms have to collect and analyse large amounts of information. Big data analytics or AI can thus act as a new enabler of the innovation process (Haskel and Westlake, 2017; Cockburn, Henderson and Stern, 2018).

¹⁹ The higher investment intensity of digital firms is also observed when zooming into sectors and size classes.

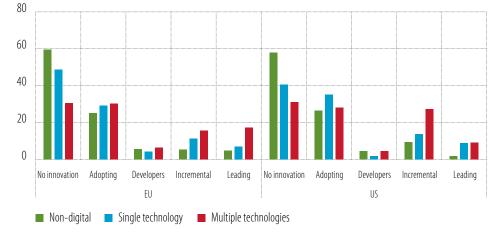


Figure 23 Innovation profiles (in %), by digital intensity

Source: EIBIS 2020.

Note: See Figure 11 for the definition of innovation profiles and note to Figure 13 for the definition of digital adoption. Firms are weighted using weighted by value added.

Looking ahead to the next three years, the investment priority for digital firms is to develop new products, processes or services. Firms that have implemented multiple digital technologies more often report that they plan to invest (Figure 24). They also tend to have different investment priorities. For non-digital EU firms, replacing capacity (including existing buildings, machinery, equipment and IT) is more often mentioned as the investment priority for the next three years.

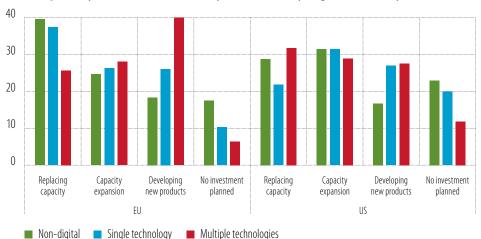


Figure 24

Investment priority over the next three years (in %), by digital intensity

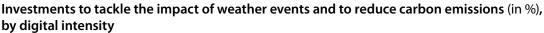
Source: EIBIS 2020.

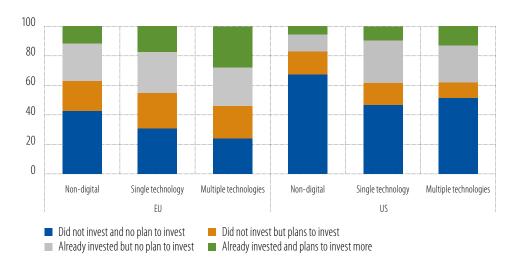
Note: See note to Figure 13 for the definition of digital adoption. Firms are weighted using value added. Question: Looking ahead to the next three years, which of the following is your investment priority?

Digital firms are also more likely to invest to meet the challenges of climate change, such as preparing for extreme weather events and reducing their carbon emissions. Firms with multiple technologies tend to report that they have plans to invest more in climate adaptation in the next three years (Figure 25). In addition, EU firms make green investments more often than US firms. These findings support the idea that

digital technologies can serve as critical enablers for attaining the goals of the European Green Deal. If used in the right way, emerging technologies could be critical to tackling today's environmental challenges. Examples of those technologies include smart urban mobility, precision agriculture, sustainable supply chains, environmental monitoring and better disaster alert systems. The potential of these digital tools needs to be unlocked if the European Union is to meet the Paris Agreement targets.

Figure 25





Source: EIBIS 2020.

Note: See note to Figure 13 for the definition of digital adoption. Firms are weighted using value added. Question: Thinking about investments to tackle the impacts of weather events and reduction in carbon emissions, which of the following applies?

Digital firms are more prone to thinking that reducing carbon emissions will positively affect the market for their products and their reputation over the next five years. Limiting global warming requires a reduction of global carbon emissions over the coming decades. Digital firms, especially firms that have implemented multiple technologies, more often report that global efforts to reduce carbon emissions will positively impact their business in the next five years, increasing the market for their products and their reputation (Figure 26). Reducing global carbon emissions is expected to change demand for goods and services as consumer preferences shift in the medium term, according to firms that have already implemented digital technologies. Shareholders' and customers' climate concerns may also affect the reputation of some companies. Overall, this evidence is in line with the other findings, such as investments to tackle transition risks from climate change (Figure 25), where digital firms report more often that they already focused on green investments.

The digital transformation can support the transition to a low-emission economy, but action must be taken now. As outlined above, a shift in consumer preferences linked to a reduction in carbon emissions is expected to affect global supply chains and change demand for goods and services. However, the proliferation of cutting-edge technologies – such as advanced robotics, artificial intelligence, blockchain technology and 5G telecommunication – is contributing to rapidly growing energy consumption. Innovative businesses, policymakers and consumers need to come together to take responsibility for this complex issue, take timely action to successfully leverage digital technologies and enable the much-needed shift towards a circular economy, in line with the priorities of the European Green Deal.

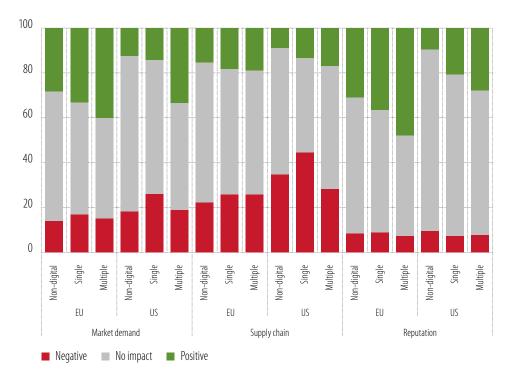


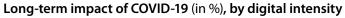
Figure 26 Impact of reducing global carbon emissions in the next five years (in %), by digital intensity

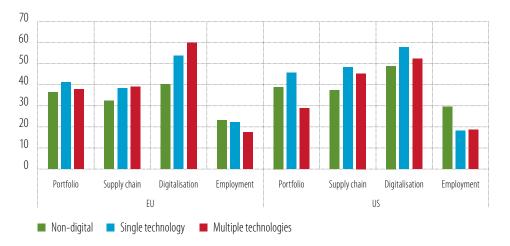
Source: EIBIS 2020.

Note: See note to Figure 13 for the definition of digital adoption. Firms are weighted using value added.

Question: What impact, if any, will this transition to a reduction in carbon emissions have on the following aspects of your business over the next five years? A positive impact, a negative impact, or no impact?

Figure 27





Source: EIBIS 2020.

Note: See note to Figure 13 for the definition of digital adoption. Firms are weighted using value added. Question: Do you expect the coronavirus outbreak to have a long-term impact on any of the following?

Following the coronavirus pandemic, investment in digitalisation has become an urgent priority. The majority of digital firms expect digital technologies to become more important in the future. More than 57% of digital firms in the European Union and 55% in the United States expect digital technologies to gain importance in coming years, compared with 40% of non-digital firms in the European Union and 49% in the United States. The large share of non-digital firms that do not take the digital transformation seriously implies that the digital divide between firms may grow over time (Rückert, Veugelers and Weiss, 2020). Digitalisation may also further increase the market power of firms that are already in a privileged market situation, reinforcing the idea of winner-takes-all dynamics as a result of digital technologies (Gutiérrez and Philippon, 2017; Calligaris, Criscuolo and Marcolin, 2018; De Loecker, Eeckhout and Unger, 2020). In addition, digital firms report less often that the COVID-19 outbreak will lead to a permanent reduction in employment, especially in the United States.²⁰ When it comes to the expected long-term impact of COVID-19 on services, product portfolios, and supply chains, the responses of digital and non-digital firms are similar.

²⁰ This result could also be driven by digital firms, which state more often that they intend to reduce investment, whereas non-digital firms state more often that they will not invest at all.

Conclusion and policy implications

Policymakers in the European Union should be concerned about the lack of investment in digital technologies by many EU firms, as the COVID-19 crisis is likely to exacerbate the digital divide. The European Union is not only lagging behind in digital innovation, but also in digital adoption, potentially jeopardising the long-term competitiveness of the European Union. A substantial share of EU firms are not implementing any digital technology and have no plans to start investing in digitalisation. Unprecedented changes in workforce arrangements make the crisis a unique opportunity to raise awareness and encourage non-digital firms to reassess their management strategies and to start taking digital transformation seriously – before it is too late. Effective policy implementation is especially needed since the COVID-19 crisis may exacerbate the digital divide between firms. The crisis may foster digital adoption rates, as some firms realise the benefits of implementing digital products, switching to robotic production, using internet of things applications or harnessing big data and artificial intelligence. On the other hand, firms that fail to innovate risk being left behind.

To address the long-term impact of COVID-19, the European Union will need to create better conditions for innovation and the digital transformation. To ensure that EU firms do not lose ground compared to their US peers, policymakers should strive to preserve a well-functioning, competitive and integrated EU market environment that will push firms to invest more in digitalisation. For example, EU members need to review regulations that prevent firms from growing and reaching the size needed for the successful adoption and integration of multiple technologies within their business. Policy action should develop measures to improve the digital skills of workers through training, and make it easier to finance investments in digital technologies.

Europe should aim to generate more new leaders in digital sectors and put pressure on leading companies to help push the technological frontier and foster the green transition. A weak European digital sector means that EU companies and citizens will lack ownership of their data, leaving the data to be controlled outside the European Union. It is also critical to support fast-growing small and young innovative firms, to counter winner-takes-all dynamics that can be caused by digital technologies. Supporting young firms requires improvements to competition, environmental, data and trade regulations, and the rapid implementation of the digital single market in the European Union.

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Data annex

Glossary of terms and acronyms