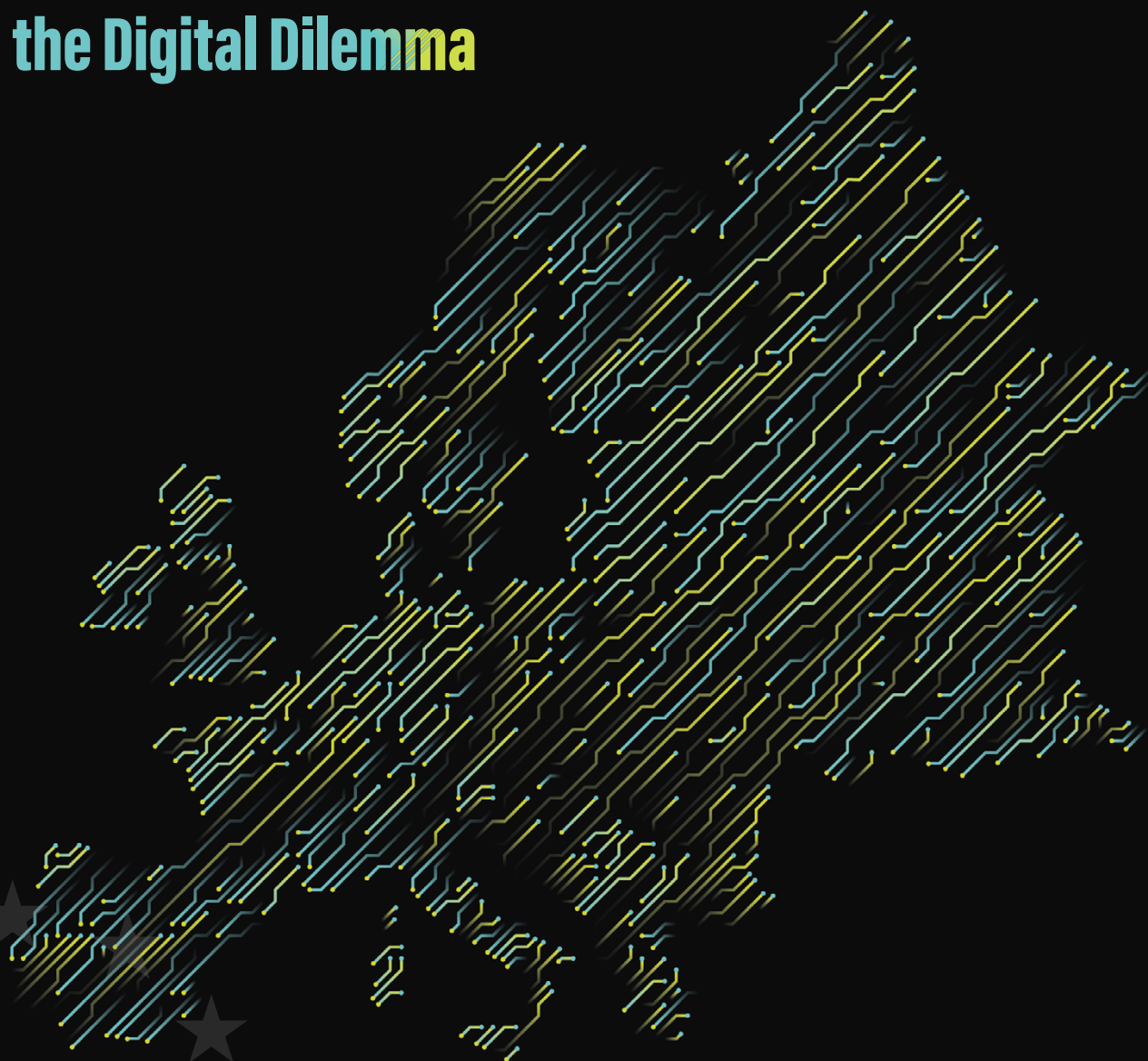


# EUROPE 4.0

## Addressing the Digital Dilemma



Mary Hallward-Driemeier  
Gaurav Nayyar  
Wolfgang Fengler  
Anwar Aridi  
Indermit Gill



WORLD BANK GROUP

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 Federal Ministry  
Republic of Austria  
Finance

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and Development / The World Bank  
1818 H Street NW  
Washington DC 20433  
Telephone: 202-473-1000  
Internet: [www.worldbank.org](http://www.worldbank.org)

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#### **Cover and layout design and typesetting:**

Piotr Ruczyński, London, United Kingdom

#### **Graphics:**

Patrick Ibay, Washington, DC, United States  
Piotr Ruczyński, London, United Kingdom

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# Foreword

Today, a digital transformation represents the key driver of a significant shift occurring in our economies, societies, and personal lives. In the context of COVID-19, digital connectivity has become an even more essential public good and prerequisite for business and operational continuity. Digital technologies can, and are, enabling more economic activities to happen — and to happen safely — albeit unevenly across firms, sectors, and locations. Given this context, the lessons discussed in this report are all the more relevant in our fight to reduce inequality and achieve a quicker, more resilient recovery in Europe.

Much is at stake. The goal is not solely about being competitive, but rather about being competitive in an environment that can also ensure economic benefits reach a wide range of firms — including new and small businesses, as well as those in less developed locations. The evidence provided in this book demonstrates how digital technologies are (and are not) living up to their potential. Such evidence is crucial for informing recommendations to policymakers as they strive to achieve the complementary goals of competitiveness, inclusion, and convergence.

While COVID-19 adds a layer of urgency to this agenda, the longer-term issues that underpin this digital dilemma lie at the core of this work. The report aptly informs three distinct policy debates:

- ***Does completing the transition to the data economy need more champions or more markets?*** As Europe grapples with completing its transition to a digital single market, it faces difficult choices. Should policies focus on technology more narrowly and emphasize the emergence of champions or take a broader approach? How should it approach the complementary factors that help determine the pace and pattern of technological progress — such as skills, infrastructure and the broader regulatory environment? Scaling digital markets and accelerating the transition to using them more widely may make it more viable for champions to emerge and thrive.
- ***Can Europe's regulatory choices be a source of comparative advantage, influencing the values and standards of new technologies globally?*** Europe remains a global leader in updating its competition policies addressing new features of data-driven businesses, as well as regulating data privacy protections. Together these regulatory choices will shape the contestability of data markets, influencing the emergence of digital global players and affecting the extent to which Small-and-Medium Enterprises — as well as new entrants — can simultaneously access data and innovate. Decisions about new technologies will also have broader cultural impacts — particularly on how artificial intelligence will be used to provide opportunities for people.
- ***Is leapfrogging possible or is more attention needed to diffuse technologies that can facilitate catching-up?*** Concerns about competitiveness can focus attention on the frontier. But the variation across — and within — countries is striking, in terms of access and readiness to use digital technologies. Diffusion is not happening quickly or automatically. To raise productivity more widely, providing support for more firms and locations to catch-up will be critical for ensuring more people are included and to enhance convergence.

In discussing the policy choices available to regulators, this report lays out the possibility of embracing new technologies in ways that can contribute to competitiveness, inclusion, and convergence. Europe still has the chance to attain *Europe 4.0*; it should take that chance.



Anna Bjerde  
Vice President  
Europe and Central Asia



# This Work

This is the third in a series of reports about convergence and inclusion in Europe.

*Golden Growth* (2012) was the first of the series. Examining five decades of growth it finds that the European growth model has been a powerful engine for economic convergence, helping developing countries in Europe to catch up with their richer neighbors and become high-income economies. Trade policies opened opportunities to lower-income countries, but wealthier states also instituted the most redistributive fiscal mechanisms in the world. This ‘convergence machine’ underscores the extent of Europe’s commitment to inclusion and convergence, and why they are treated on a par with competitiveness as Europe’s triple objectives.

*Growing United* (2017) examined how this convergence machine was slowing down. It analyzed how technological change is limiting the benefits to some firms and workers, looking at the policy agenda to improve the business environment for more firms to upgrade and strengthen skills so that more workers can benefit from more productive jobs. It also looked at how social protection systems can protect those being displaced, while also covering new forms of work, such as jobs in the growing gig economy.

*Europe 4.0* (2020) differentiates across types of data-driven technologies to provide more nuanced insights into where technologies are contributing to the goals of inclusion and convergence, and where tensions are emerging with efforts to increase competitiveness. The emphasis is on expanding firms’ access to new opportunities, including young and small firms, firms in lagging regions, and firms in new accessing countries. The potential for inclusion and convergence differs across types of digital technologies. Europe faces a dilemma as the technologies in which it is most competitive are those that concentrate benefits among larger firms and in established hubs, while those technologies with the greatest potential to contribute to inclusion and convergence are those where European firms are least competitive. However, it also argues that with the right mix of policies, a dynamic and inclusive digitally enabled future is possible; Europe can attain *Europe 4.0*.

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The main authors and contributors of this report were:

- The Overview: Mary Hallward-Driemeier, Gaurav Nayyar and Wolfgang Fengler.
- Chapter 1: Indermit Gill and Mary Hallward-Driemeier, with inputs from Kenan Karakulah.
- Chapter 2: Mary Hallward-Driemeier, Gaurav Nayyar, Indermit Gill and Wolfgang Fengler
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- Chapters 6, 7 and 8: Mary Hallward-Driemeier and Anwar Aridi, with inputs from Daniel Querejazu and Alexandra Soininen.

The project team commissioned a series of background papers to contribute to the research process, fill in knowledge gaps, and extend the core team's expertise. The following list includes the research papers and the respective partners.

- Aridi, Anwar and Daniel Querejazu. *Manufacturing a Startup: A case study of Industry 4.0 Development in the Czech Republic* (World Bank Group)
- Aridi, Anwar and Urška Petrovčič. *Big Tech, Small Tech, And The Data Economy: What Role For EU Competition Law?* (World Bank Group)
- Bal, Ravtosh. *Approaches to Industry 4.0 Technologies: Europe, China, and the United States* (Duke University)
- Balland, Pierre-Alexandre and Ron Boschma. *Industry 4.0 and the New Geography of Knowledge Production in Europe* (Utrecht University)
- Cathles, Alison, Gaurav Nayyar and Désirée Rückert. *Digital Technologies and Firm Performance: Evidence from Europe. EIB Working Paper 2020/06, April 2020*, European Investment Bank, Economics Department.
- Cifollilli, Andrea, Alessandro Muscio and Alasdair Reid. *Comparative Advantages in Industry 4.0 Key Enabling Technologies: Evidence from Horizon 2020 Research Projects* (European Future Innovation System Center)
- Crespo, Jesus, Sebastian Lutz and Michael Pfarrhofer. *Modelling and Projecting Digitalization Trends in Europe* (Vienna University of Economics and Business)
- Foray, Dominique and Charles Ayoubi. *Artificial Intelligence and Big Data in the Swiss Healthcare Sector* (École Polytechnique Fédérale de Lausanne)
- Hallward-Driemeier, Mary and Gaurav Nayyar. *Have Robots Grounded the Flying Geese? Evidence from Greenfield FDI in Manufacturing*, World Bank Policy Research Working Paper #9097. Washington D.C., World Bank Group.
- Padilla, Pierre, Nicholas Vonortas, Yury Dranev, Veronika Belousova, Emmanuel Boudard. *Analyzing the Deployment of Blockchain and Distributed Ledger Technologies in the Financial Sector* (N-ABLE)
- Posselt, Thorsten, Riad Bourayou and Sebastian Haugk. *Characterizing the New Data Economy: Big Shifts and Their Impact on Europe and the Wider Global Economy* (Fraunhofer Institute)
- Van der Marel, Erik. *Data Policy Restrictions, Firms' Technology Adoption and Productivity Performance* (European Centre for International Political Economy)

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Piotr Ruczyński designed the cover and the layout and typeset the report while Patrick Ibay created the graphics. Peter Milne was the principal editor. The team also thanks Clara Calaveras, Cherry Hodak, and Dalia Shehata Ali for administrative and logistics support.

# Abbreviations

3D	Three Dimensional
AI	Artificial Intelligence
B2B	Business-to-Business
B2C	Business-to-Consumer
BDLT	Blockchain and Distributed Ledger Technology
C2C	Consumer-to-Consumer
CRM	Customer Relationship Management
EC	European Commission
ECB	European Central Bank
EEA	European Economic Area
EIB	European Investment Bank
ERP	Enterprise Resource Planning
EU	European Union
FDI	Foreign Direct Investment
FTE	Full-time equivalent
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GPT	General Purpose Technology
GVC	Global Value Chain
HIC	High-Income Country
ICT	Information and Communications Technology
IoT	Internet of things
IPO	Initial Public Offering
IT	Information Technology
LMIC	Low- and Middle-Income Country
M2M	Machine-to-Machine
M&A	Mergers and acquisitions
ML	Machine Learning
NUTS	Nomenclature of Territorial Units for Statistics
OECD	Organisation for Economic Co-operation and Development
R&D	Research and Development
SME	Small and Medium-sized Enterprise
UNCTAD	United Nations Conference on Trade and Development
VAT	Value-added Tax
VC	Venture Capital

# Countries and Regions

<b>EU</b>	<b>EU-14</b>	<b>North</b>	Denmark Finland Ireland Sweden	DK FI IE SE
		<b>Central</b>	Austria Belgium France Germany Luxembourg Netherlands	AT BE FR DE LU NL
		<b>South</b>	Greece Italy Portugal Spain	GR IT PT ES
	<b>EU-13</b>	<b>North</b>	Estonia Latvia Lithuania	EE LV LT
		<b>Central</b>	Croatia Czech Republic Hungary Poland Slovak Republic Slovenia	HR CZ HU PL SK SI
		<b>South</b>	Bulgaria Cyprus Malta Romania	BG CY MT RO
	<b>EFTA</b>		Iceland Liechtenstein Norway Switzerland	IS LI NO CH
	<b>EU candidate</b>		Albania Montenegro North Macedonia Serbia Turkey	AL ME MK RS TR
	<b>Other Europe</b>		Bosnia and Herzegovina Russian Federation United Kingdom	BA RU GB
<b>Outside Europe</b>		Australia Brazil Canada Chile India Israel Japan Republic of Korea Mexico New Zealand	AU BR CN CL IN IL JP KR MX NZ	



# OVERVIEW

**Europe faces a digital dilemma.** New digital technologies can help Europe<sup>1</sup> become more competitive. However, while some of these new technologies create or expand access to markets for smaller firms and in lagging regions, others can create challenges for the European *convergence machine* if they concentrate economic activity in large firms and leading regions. As it happens, digital technologies, such as matching platforms, have the greatest potential for market inclusion and convergence, but this is where Europe remains less competitive. In contrast, European firms are particularly strong in technologies that combine data with production, such as smart robotics and 3D printing. While this helps Europe's competitiveness, it also widens the divide between large and small firms, and leading and lagging regions.

**Europe 4.0 is attainable.** Europe 4.0 is about embracing new digital technologies associated with Industry 4.0 in ways that contribute to Europe's triple imperative of *economic competitiveness*, *market inclusion*, and *geographic convergence*, while also being aligned with its social values. A coherent set of policies that strengthens competitiveness in technologies where the potential for inclusion and convergence is strongest, while broadening access to opportunities in technologies that otherwise concentrate benefits, is needed to address this digital dilemma for Europe 4.0. Reforms and investments can help new digital technologies achieve Europe's triple objectives without compromising its social values by making use of the following:

- *Scaling markets*—completing the digital single market and closing gaps in 'analog complements' such as infrastructure, skills and logistics to achieve greater competitiveness, inclusion and convergence;
- *Shaping the commercial use of data*—addressing challenges posed by artificial intelligence and new types of market dominance to balance competitiveness and inclusion aligned with values of data privacy; and
- *Smoothing technology adoption*—complementing investments in frontier innovation with digital catch-up through supporting applied R&D and strengthening management capabilities so more smaller firms and firms in lagging regions can absorb new technologies.

**The COVID-19 pandemic has highlighted the importance of the data economy—and raised the risks in meeting Europe's economic objectives if the digital dilemma is not addressed.** Companies that have embraced digital technologies are better able to cope with the disruptions posed by the pandemic. This is done, for example, through enabling more remote working, smart factories that have been able to keep operating uninterrupted, 3D printing of product parts stuck in the value chain, and the use of artificial intelligence to re-assess and plan activities. Digital platforms, particularly larger incumbents, have an important advantage in Europe given new social distancing requirements. In April 2020, e-commerce in Poland experienced a 200 percent increase compared to the same period in the previous year. In Belgium, e-commerce had also increased over a 100 percent (ccinsight.org). At the same time, locations where the uptake of digital technology is lower have not had the same opportunities to extend opportunities for work, exacerbating geographic divides. Going forward, countries and companies that embrace Industry 4.0 will be better placed to face the challenges, but also capitalize on the opportunities, of an increasingly globalized world.

## THE UNEVEN STATE OF DIGITAL TECHNOLOGY IN EUROPE

**Europe has converged in digital infrastructure, but more needs to be done to accelerate the commercial use of digital technologies.** Europe has done well in expanding access to broadband. At least 69 percent of households have access to broadband in every European region, and over 90 percent of households are fully connected in most regions. This demonstrates remarkable progress over the past decade in closing gaps in access to digital infrastructure (Map O.1.a.1 and O.1.a.2). But convergence between regions in the use of digital services has been slow. Even today, in many parts of Southeastern Europe, southern Italy and parts of Portugal,

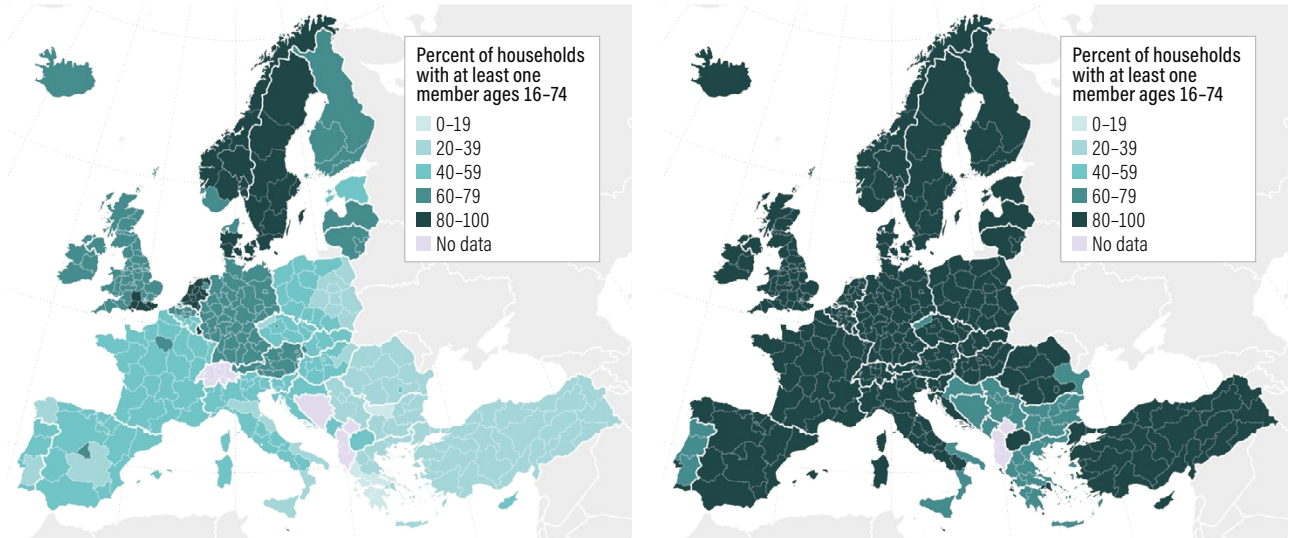
less than one-third of the population use the internet to order goods or services, unlike in Belgium, Germany, the Netherlands, the United Kingdom or Scandinavia, where three-quarters of the population shop online (Map O.1.b.1 and O.1.b.2).

**MAP O.1** Quicker convergence in access to digital opportunities than for outcomes

a. Households with broadband access

1. 2008

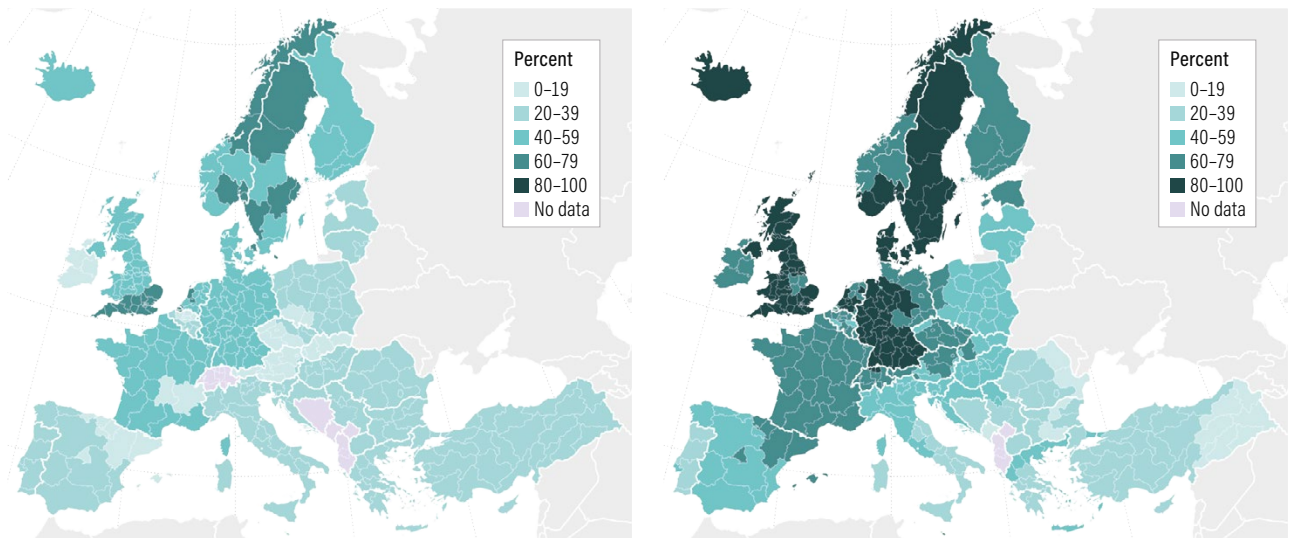
2. 2019



b. Percent of individuals aged 16 to 74 who ordered goods or services online in the past year

1. 2008

2. 2019



Source: Authors' calculations based on Eurostat.

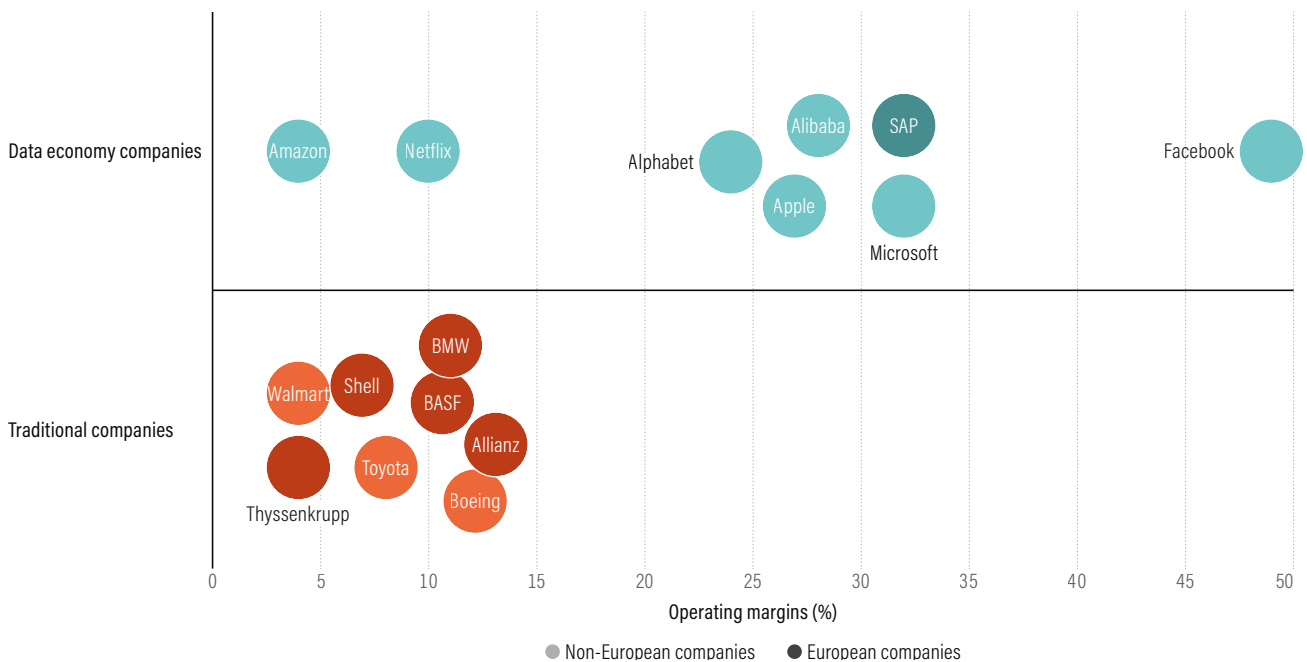
Notes: The maps reflect NUTS2 level data. Due to lack of data, Poland, Germany, the United Kingdom, Turkey, and Greece reflect NUTS1 level data. In addition, France reflects NUTS1 level data in 2019 and national data in 2008 (except for Île-de-France and Auvergne - Rhône-Alpes in 2008).

**Many of Europe's industrial companies are global leaders, but Europe can lay claim to only a few global technology giants.** While Europe has strong companies in the traditional sectors, it has few large tech and data companies, which are now far more profitable (Figure O.1). Today, the top companies in the world are mostly tech companies headquartered outside Europe, such as Alphabet, Apple, Facebook, Microsoft, Alibaba,



and Tencent. SAP, which is the most valuable company in Germany and the second-most-valuable company in Europe (after Royal Dutch Shell), is Europe's sole data company among the global leaders, at number 12. However, Europe is well placed in digital technologies that combine data with machines (e.g., smart robots). Leading industrial firms in Europe anchor many global value chains, and are well positioned both as the producers and users of smart automation equipment. The rapidly rising global middle class, especially in Asia, which will demand high-value manufactured goods, also provides a new economic opportunity for Europe in this space.

**FIGURE 0.1** Europe's traditional leaders are strong, but new data companies are significantly more profitable — European firms are not so well represented among them

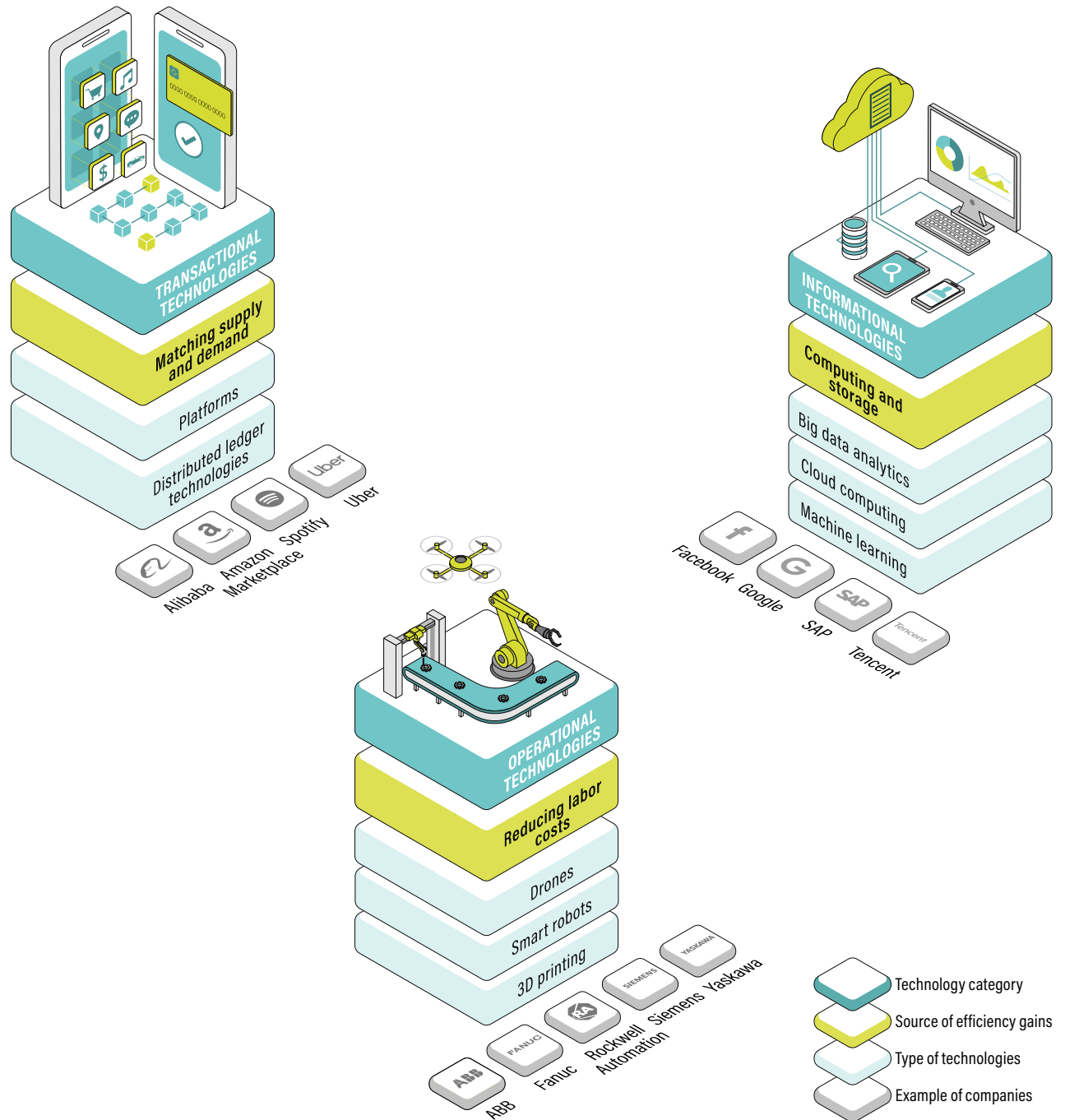


Source: Authors' calculations based on Bloomberg, December 2019.

## VIEWING IMPACTS OF NEW DIGITAL TECHNOLOGIES THROUGH THE LENS OF EUROPE'S ECONOMIC OBJECTIVES HIGHLIGHTS THE DILEMMA

**New digital technologies should not be seen as monolithic, because their dynamics vary based on differences in their underlying source of efficiency gains.** This report focuses on three types of process technologies within Industry 4.0 that are driven by the use of data and can be applied to a range of sectors. *Transactional technologies* better match supply and demand to facilitate market transactions by lowering information asymmetries; examples include digital ecommerce platforms and blockchain. *Informational technologies* exploit the exponential growth of data and the reduced cost of computing; examples include business management software, cloud computing, big data analytics, and machine learning. *Operational technologies* combine data with physical automation to reduce production costs, including labor, materials and, in many cases, energy; examples include smart robots, 3D printing and the Internet of Things (IoT). Differences in the economic drivers of technological change imply different degrees of diffusion or concentration of opportunities.

**FIGURE 0.2** Differentiating three types of digital technologies by sources of efficiency gains



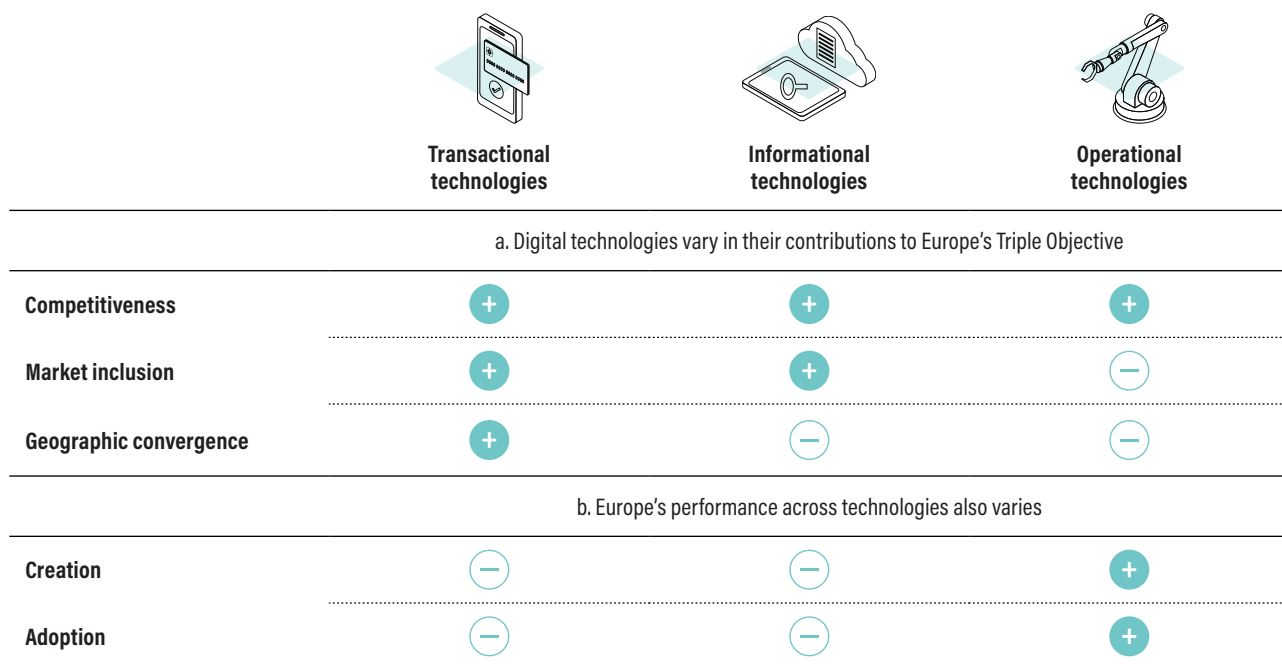
Source: Europe 4.0 team.

**These three digital technologies therefore differ in their contributions to Europe’s triple objective of economic competitiveness, market inclusion, and geographic convergence.** New digital technologies create new tensions across Europe’s three goals of being competitive, ensuring inclusive access to market opportunities, and fostering convergence across regions. The occurrence of such trade-offs depends on the underlying characteristics of the technologies, as well as the necessary complementary factors, such as the quality of infrastructure, skills

and governance. Transactional technologies help connect firms to larger markets at very low cost and, as such, can help smaller firms and firms in more remote locations to be more productive. Informational technologies, such as enterprise resource planning (ERP) software or cloud computing, provide efficient services at a low cost that can also help smaller firms. However, while in theory they should help more remote locations, the quality of supporting infrastructure and skills to use them are not always available in more lagging regions. Meanwhile, operational technologies, such as autonomous robots, require higher upfront investments and rely on more scale economies, thus favoring larger firms. The greater use of ‘smart’ automation is also serving to concentrate more production in existing hubs. Thus, as shown in Figure O.3.a, the technologies vary in how they contribute to Europe’s three goals.

**Europe’s performance also varies across technologies, in terms of the number of frontier companies and in the rate of firm adoption.** The evidence shows that there are few leading global firms in either the transactional or informational technologies, and rates of adoption are fairly low. In the case of cloud computing, there is even divergence in adoption rates across countries, with just a few countries having a significant share of firms using it. However, Europe has many leading firms in operational technologies and rates of adoption are also fairly high (see Figure O.3.b).

**FIGURE O.3** Europe faces a digital dilemma between its objectives and its performance



Source: Europe 4.0 team.

Taken together, Europe faces a digital dilemma: where impact on inclusion and convergence is strongest, Europe’s performance is modest; and where its performance is strongest, the impact on inclusion and convergence is weaker.

**This report provides new evidence of such a digital dilemma in Europe.** Operational technologies are where European firms are most competitive, but these tend to concentrate opportunities in larger firms, and existing production and knowledge hubs. Transactional technologies have the maximum potential to promote market inclusion and geographic convergence, but this potential is only being partially realized and few European transactional digital platforms are globally competitive. Informational technologies fall in between, with some market inclusion, but little spatial convergence. And over time, the newest informational technologies have a pattern more like operational technologies, with benefits being realized by larger firms in leading regions. Here too,

technology adoption is not widespread, and Europe can lay claim to few companies that are global leaders. This imbalance between objectives and performance needs to be addressed to avoid current trade-offs and realize the full potential new technologies offer. This will be all the more important in light of the COVID-19 economic crisis.

# THE IMPACTS OF NEW DIGITAL TECHNOLOGIES ON EUROPE'S TRIPLE OBJECTIVE

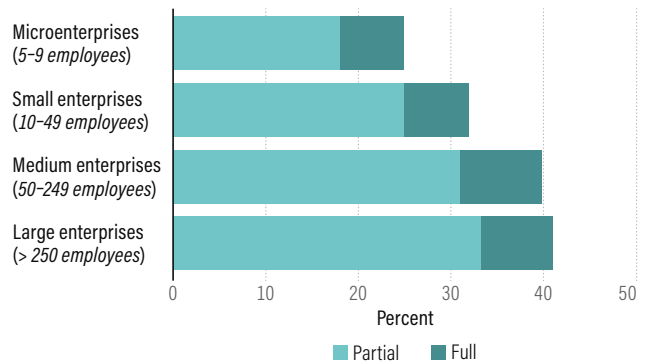
## Transactional technologies strengthen all three objectives

Transactional technologies strengthen economic competitiveness, market inclusion and geographic convergence, yet the lack of adoption across firms leaves vast unrealized potential.

**Transactional technologies raise economic competitiveness.** The use of B2C digital platforms is positively associated with labor productivity in Europe. In fact, adopters of B2C digital platforms are more productive than non-adopters across the size distribution of firms (Cathles, Nayyar, and Rückert 2020). These productivity benefits have been enabled by data-driven decision-making. For example, Booking.com helped its clients to realize an average of 7 percent more revenue by helping them identify consumers whose data indicated that they would be willing to pay more (Li et al. 2019). Similarly, estimates from Europe's financial sector suggest that blockchain and distributed ledger technology (BDLT) will roughly halve transactions costs and enable cumulative growth of 6.3 percent in EU GDP from 2021 to 2030. The BDLT applications of SettleMint — a Belgian startup — have, for example, reduced the cost of financial transactions by almost 80 percent through the removal of intermediaries and back-office needs (Padilla et al. 2019).

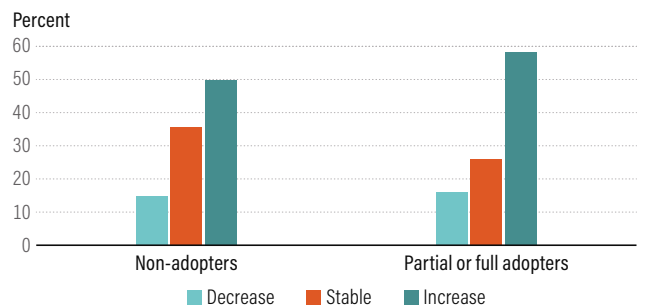
**Transactional technologies boost market inclusion.** The shares of small and medium enterprises (SMEs) using digital platforms in the EU, at 32 and 39 percent, respectively, are not notably different from large firms (Figure O.4). In sectors where this technology is most widespread, such as hotels and lodging services, countries with a higher share of firms that use online sales are also characterized by a smaller gap in labor productivity between large and small firms. For example, labor productivity in large firms is more than double that of small firms in Latvia, where the share of firms that uses online sales is less than 50 percent. In contrast, labor productivity in large and small firms is about the same in Estonia, where the corresponding share is more than 70 percent. This result is consistent with the fact that digital platforms reduce the fixed costs of entering new markets by reducing information asymmetries associated with matching buyers and sellers. The use of digital platforms is also associated with job creation. Figure O.5 shows that 60 percent of firms in the EU that partially or fully implemented platforms in their

**FIGURE O.4** The share of SMEs using digital platforms in the EU is not very different from large firms, 2019



Source: EIB-WBG background paper by Cathles, Nayyar and Rückert (2020).

**FIGURE O.5** Trends in employment growth over the past three years, by digital platform adopters, 2019

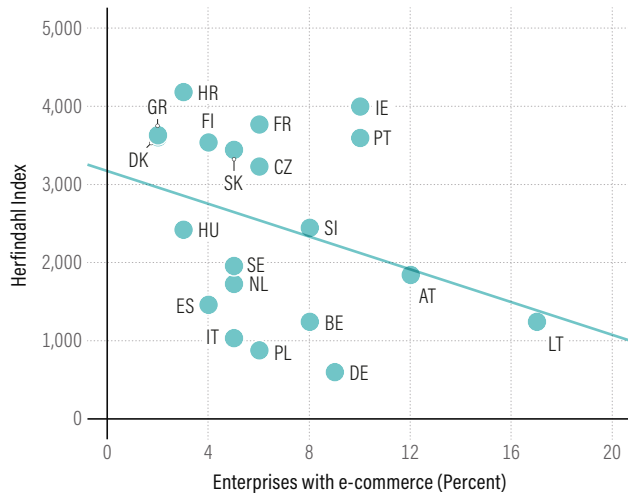


Source: EIB-WBG background paper by Cathles, Nayyar and Rückert (2020).

business experienced an increase in employment growth over the past three years, compared with 50 percent of firms that did not adopt these technologies. A similar share, around 10 percent of firms, among both adopters and non-adopters experienced a decline in employment growth.

**Transactional technologies aid geographic convergence.** In the information and communication services sector, where this technology is most widespread, economies with a higher share of firms that use e-commerce platforms for digital transactions are characterized by a lower Herfindahl index of concentration, based on the

**FIGURE 0.6** Higher use of e-commerce platforms is associated with lower spatial concentration in ICT services, 2018



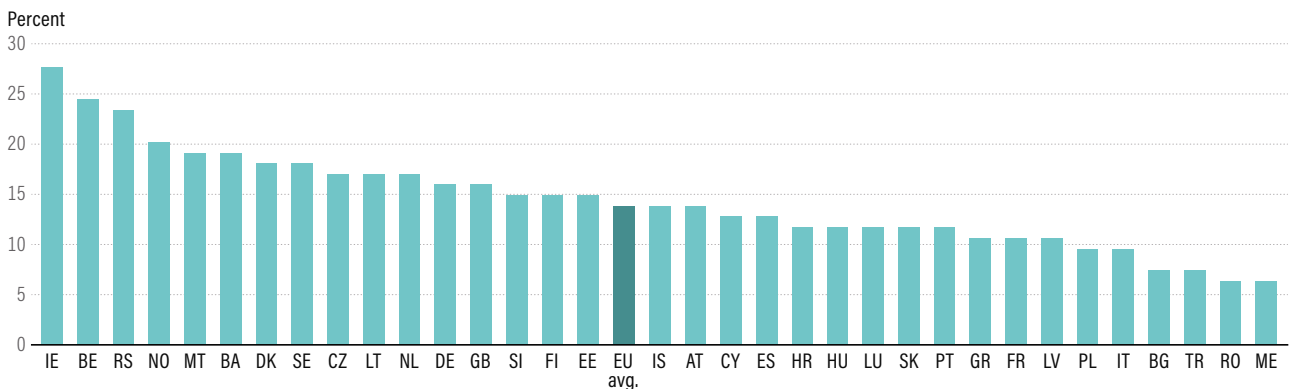
Source: Authors' calculations, based on Eurostat.

Note: The Herfindahl index of concentration is based on the number of firms at the NUTS2 level

number of workers at the NUTS2 level (Figure O.6). For example, the regional concentration of economic activity in Greece, where 2 percent of firms used e-commerce platforms, was more than three times that in Lithuania where the corresponding share was close to 20 percent. This is consistent with the fact that e-commerce platforms enable firms in remote areas to access markets through their supply chains. Digital platforms also make remote delivery possible for a wider range of professional services tasks. A computer programmer in Serbia, for example, can remotely provide data or code to customers in France through Upwork, oDesk, and Freelancer. On a per capita basis, Romania and Serbia are among the bigger emerging suppliers in the online freelancing market (Graham et al. 2017). The economic effects of BDLT implementation will be much more significant in Eastern Europe, where the financial systems are weaker than in Western and Northern Europe. It is estimated that, by adding to the investment, corporate and retail banking markets, by 30, 10 and 30 percent, respectively, the application of BDLT will result in an 8.0 percent increase in Romanian GDP by 2030, compared with 6.2 percent BDLT-enabled increase in EU GDP (Padilla et al. 2019).

**The lack of widespread adoption of transactional technologies by firms across Europe reflects vast unrealized potential, and market leaders remain few and far between.** While the use of digital sales and e-commerce platforms is associated with higher labor productivity in Europe, less than one-fourth of firms used a B2C website to sell online in Europe in 2018. While the EU14 North and Central countries feature prominently among countries where diffusion is greatest, Serbia (22 percent), Bosnia and Herzegovina (18 percent), the Czech Republic and Lithuania (both 16 percent) are also among the top ten in Europe (Figure O.7). There

**FIGURE 0.7** The share of firms that use a B2C website or app to sell online in Europe is far from universal, with both EU14 countries and others constituting the top ten



Source: Authors' calculations, based on Eurostat.

is also little evidence of catch-up across countries. For example, in 2014, the Czech Republic had among the highest share of firms that used a B2C website to sell online, at 20 percent, and Romania among the lowest at 5 percent. Yet, the Czech Republic also experienced a 5 percent increase in this share between 2014 and 2018, while Romania experienced a 5 percent decline. With regard to technology creation, nearly three-quarters of the \$4.3 trillion value of digital platforms is accounted for by those in North America, compared with 20 percent by those in Asia, and less than 5 percent by those in Europe (Evans and Gawer 2016). Furthermore, digital platform enterprises and app developers in Europe are overwhelmingly concentrated in major urban centers such as London, Paris, Madrid, Berlin, Helsinki, Amsterdam and Barcelona (Szczepański 2018). Among the global leaders in digital platforms that enable market matching, only Spotify is European, and even then it is listed on the New York Stock Exchange.

## Informational technologies help economic competitiveness and market inclusion

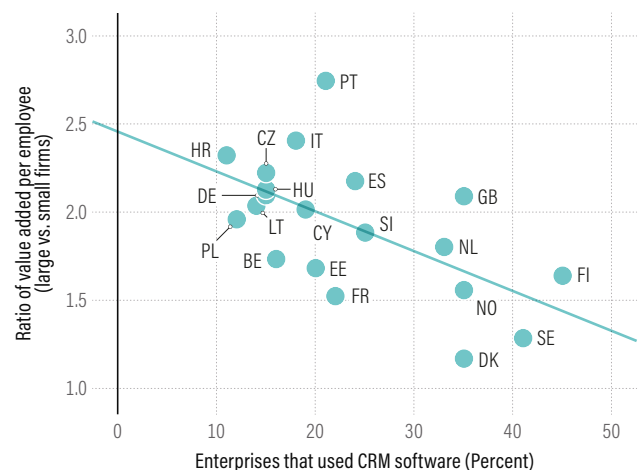
Traditional informational technologies strengthen economic competitiveness and market inclusion but not economic convergence, and the lack of diffusion leaves vast unrealized potential

**Traditional informational technologies raise economic competitiveness.** Based on data from 20 European countries and 22 industries, Gal et al. (2019) find that greater adoption of informational technologies — ERP software, customer relationship management (CRM) software, and cloud computing — in an industry is associated with higher productivity growth for the average firm. For example, they find that a 10-percentage-point increase in the adoption of cloud computing implies a 3.5 percent higher productivity level for the average firm in five years. Furthermore, business management software could result in the reshoring of IT enabled back office processes to high-wage economies such as in Europe. Sutherland Global Services, an outsourcing company in Rochester, NY, says it can reduce costs for its clients by between 20 and 40 percent by shifting IT work to a developing economy; but it can reduce costs by up to 70 percent if it couples business management software with its us-based workers (Lewis 2014).

**Traditional informational technologies boost market inclusion.** In information and communication services, where the use of cloud computing or business management software is most widespread, countries with a higher share of firms that adopt these technologies have smaller gaps in labor productivity between large and small firms (Figure O.8). For example, labor productivity in large firms is more than double that of small firms in Bosnia and Herzegovina, where the share of firms that use CRM software is around 10 percent. In contrast, labor productivity in large and small firms is about the same in Sweden, where the corresponding share was more than 40 percent. The fact that these technologies disproportionately benefit small firms is consistent with the low fixed cost of installing new software relative to physical capital or hardware. Cloud computing, for example, eliminates upfront capital expenditures associated with information storage and exchange.

**However, at least in Europe, traditional informational technologies have not enabled greater geographic convergence.** In principle, the use of cloud computing and business management software should expand opportunities in more locations, because they reduce coordination costs. However, the use of cloud computing and business management software is not negatively associated with lower spatial concentration of economic activity in Europe’s ICT services sector, where this technology is most widespread (Figure O.9). For example, the shares of firms that use CRM software in Slova-

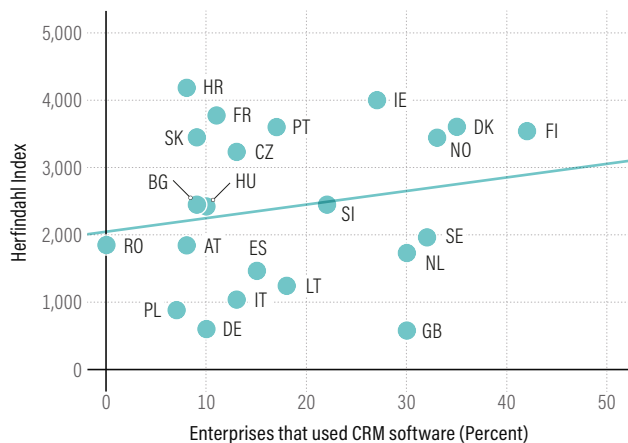
**FIGURE O.8** The more widespread use of customer relationship management (CRM) software in Europe lowers performance gaps between large and small firms in ICT services, 2016



Source: Authors' calculations, based on Eurostat.



**FIGURE 0.9** In Europe, the use of CRM software has not reduced the spatial concentration of economic activity in information and communication services, 2016

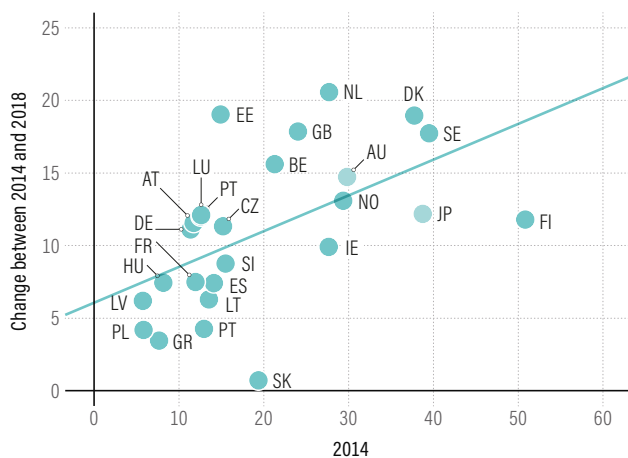


Source: Authors' calculations, based on Eurostat.

Note: The Herfindahl index of concentration is based on the number of firms at the NUTS2 level

**FIGURE 0.10** There is evidence of divergence in the share of firms using cloud computing across countries

Share of firms (%) that purchased cloud computing, level in 2014 vs change between 2014 and 2018



Source: Authors' calculations, based on Eurostat.

Denmark and Finland are notably different, at less than 10 percent and more than 40 percent, respectively, but the Herfindahl index of concentration based on the number of firms at the NUTS2 level is similar. The use of informational technologies can potentially concentrate economic activity because they rely fundamentally on better broadband access and the availability of skilled labor. For example, if management practices in Greece were at the level they are in Denmark, or if the quality of management schools was equivalent to that in Belgium, the country could expect to see a 10 percent increase in cloud computing in its knowledge-intensive industries (Andrews et al. 2018).

**The lack of widespread adoption of traditional informational technologies by firms across Europe reflects considerable unrealized potential, and market leaders remain few and far between.** While greater use of business management software and cloud computing is associated with higher labor productivity in Europe, the share of firms using these informational technologies is far from universal. EU14 North and Central countries feature prominently among those with the most widespread technology adoption, with 40 to 60 percent of firms adopting cloud computing, but Estonia (34 percent) and the Czech Republic (26 percent) were also among the top ten in Europe. At the same time, the shares of firms using cloud computing in Germany (22 percent) and France (19 percent) were uncharacteristically low. There is also evidence of divergence across European countries (Figure 0.10). For example, in 2014, Sweden had one of the highest shares of firms that used cloud computing, at 40 percent, and Poland among the lowest at around 5 percent. Nonetheless, Sweden also experienced an 18 percent increase in this share between 2014 and 2018, while Poland experienced only a 4 percent increase. With regard to their potential future participation in the development of informational technologies such as cloud computing, France, Germany, and the United Kingdom constitute less than one-third of all top 20 EU regions. The others are spread across the EU14, as well as in more recent EU countries, including the Czech Republic, Hungary and Poland (Boschma and Balland 2019).

Newer informational technologies driven by artificial intelligence (AI) raise economic competitiveness, but create challenges for market inclusion and geographic convergence

**AI-driven informational technologies also raise economic competitiveness.** The use of big data analytics and AI is positively related to labor productivity in Europe across the size distribution of firms (Cathles, Nayar and Rückert, 2020). A Microsoft survey of 152 decision-makers within automotive, aerospace, electronics, and industrial equipment companies in France, Germany, and the United States found that customer transactions data can enable firms to better forecast demand and thereby reduce inventory costs by 20 to 30

percent (Microsoft Corporation 2011). Examples also abound with respect to machine learning (ML). Google’s DeepMind team has used ML systems to improve the cooling efficiency at data centers by more than 15 percent. And the use of ML on vast amounts of data from social media profiles has improved the productivity of executive search companies that assess and match talent (Brynjolfsson and McAfee 2017). There is also evidence that highlights the capability of ML to reduce language barrier frictions, which is of first-order importance in increasing connectivity. This is especially relevant for countries in Europe. For example, the introduction of eBay’s machine translation system was associated with a 13 percent increase in exports from the United Kingdom to France, Italy and Spain (Brynjolfsson et al. 2018).

**Furthermore, newer informational technologies are less likely to enable greater market inclusion.**

Machine learning (ML) algorithms require large amounts of data to identify empirical regularities and are therefore likely to benefit large firms that are operating in large markets. As a result, the market capitalization of the five largest tech companies in the S&P 500 (Microsoft, Amazon, Apple, Google, and Facebook) that have pioneered the use of ML is larger than the sum of the market capitalizations of the 250 smallest companies in the same index (Fraunhofer 2019). Among EU28 countries in 2019, more than 25 percent of large firms in the manufacturing and services sectors used big data analytics and AI, compared with 15 percent among medium-sized firms and less than 10 percent among micro and small firms (Figure O.11). ML is also increasingly able to automate routine cognitive tasks that could previously only be done by people. For example, ML algorithms can function as robo-lawyers that can plough through information and suggest legal strategies (Baldwin 2019). Similarly, sales and customer interactions are potentially a good fit to be automated by voice recognition ML software, such as Siri, Alexa and Google Assistant.

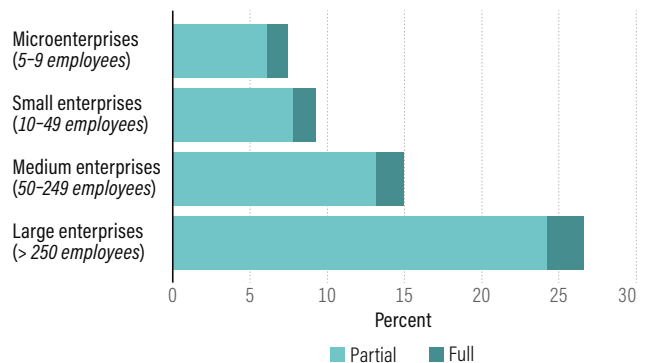
**This new wave of informational technologies is also less likely to help economic convergence.**

Malta, Estonia, Cyprus, and Bulgaria have large numbers of AI players across industry, research and startups relative to the size of their economies. However, countries in the EU14 dominate the AI landscape. The United Kingdom, Germany and France account for half of all AI players in the EU. Spain, Italy, the Netherlands and Sweden also do quite well (Craglia et al. 2018). Within countries, the potential for developing AI is high in capital city regions, such as London, Île-de-France, Comunidad de Madrid, Berlin, Vienna and Helsinki (Boschma and Balland 2019). This clustering of AI/ML hubs in major cities follows on from close ties to leading universities or proximity to investors. This relationship implies a major advantage for large agglomerations relative to smaller cities, and even metropolitan areas in lagging EU regions and member states.

**There is unrealized potential in the use of AI-driven informational technologies across firms in Europe, partly owing to its nascence, but market leaders are absent.**

While the implementation of big data analytics and AI is positively related with firm-level labor productivity in Europe, there is potential for much more. Whereas more than one-third of manufacturing and services sector firms in the Netherlands, Finland, and Denmark used big data analytics and AI in 2019, the corresponding share was about 15 percent in other EU14 countries such as France, Germany and Italy. Among the smaller more recent EU countries, Estonia stands out, with one-fourth of manufacturing and services sector firms using big data analytics and AI (Figure O.12). Furthermore, tech companies that have pioneered the use of these informational technologies are almost all headquartered outside Europe. These tech companies, such as Apple, Google, and Facebook, generate well over US\$1 million in revenues per employee per year, which exceeds the corresponding ratio for many traditional industrial companies by a factor of between 4 and 10 (Fraunhofer 2019).

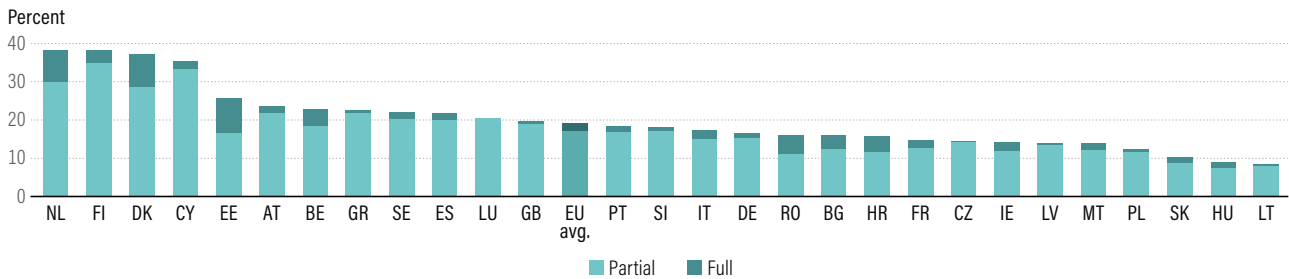
**FIGURE O.11** A notably higher share of large firms, relative to SMEs, used big data analytics and AI, 2019



Source: EIB-WBG background paper by Cathles, Nayyar, and Rückert (2020).



**FIGURE 0.12** Share of firms that partially or fully adopted AI and big data analytics, 2019



Source: EIB-WBG background paper by Cathles, Nayyar, and Rückert (2020).

## Operational technologies help economic competitiveness but not market inclusion or geographic convergence

### BOX 0.1 Data-driven technologies can support environmental goals too

The European Green Deal is a top priority of the new Commission. Data-driven technologies have strong potential to contribute to climate change mitigation by enabling greater energy efficiency in the industrial and services sectors. Big data analytics and low-power processing 'on-the-edge' technologies could allow a range of industries, from manufacturing to construction to infrastructure systems, to optimize energy and materials consumption, helping to find inefficiencies and fix them. Energy use and CO<sub>2</sub> emissions could be lowered significantly. A study by Ericsson, a Swedish telecommunications multinational, estimates that information and communication technologies (ICT), including digital technologies, have the potential to reduce global CO<sub>2</sub> emissions by up to 15 percent by 2030. Ericsson's own 5G smart factory in Tallinn, Estonia, is leveraging the IoT and ML to increase efficiency in manufacturing. And thanks to Siemens' Distributed Energy Resource Performance Monitoring and upgrading of the automation system, the Sello shopping center in Espoo, Finland, was able to achieve substantial energy savings, sustainability, and long-term improvement of indoor air quality. The benefits amounted to €125,000 in annual heat and electricity cost savings; a 271-ton reduction of annual CO<sub>2</sub> emissions; 470 MWh energy production per year; and annual profit on the energy market of €480,000 (Siemens, 2019).

At the same time, the use of data-intensive processing can use a lot of energy too. It is estimated that data centers account for 1 percent of global electricity use, and approximately 30–50 percent of the total electricity needed to run data centers goes into cooling (Science 28 Feb 2020: Vol. 367, Issue 6481, pp. 984–986; Motiva, 2011). The energy and environmental costs of using data need to be factored into data strategies, including incentives to use centralized versus 'on-the-edge' storage and computing facilities, and the extent to which big data analytics really are necessary for the growing array of issues they could be applied to.

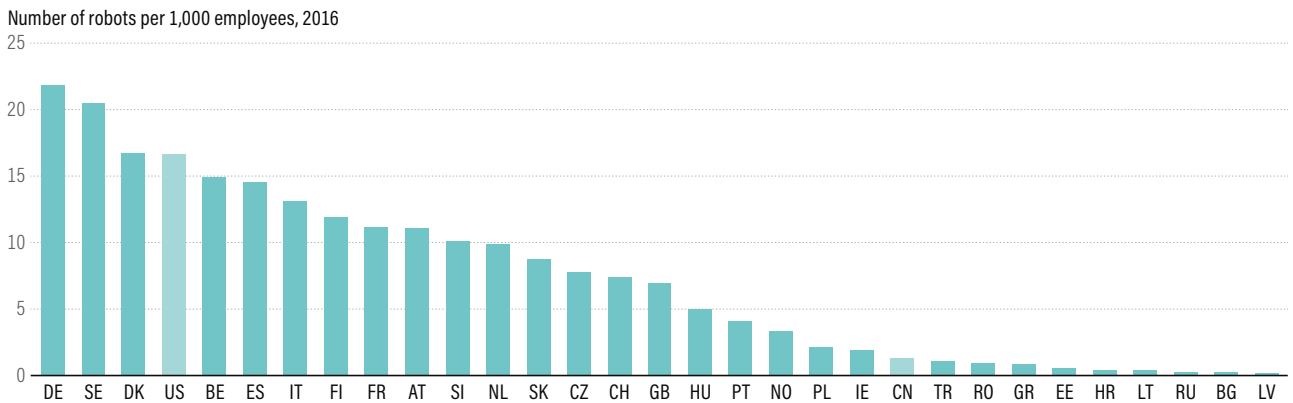
Operational technologies raise economic competitiveness, especially because European firms are among the leaders in their use and creation, but pose challenges for market inclusion and geographic convergence

### Operational technologies raise economic competitiveness.

The use of industrial robots raised annual labor productivity growth by 0.36 of a percentage point between 1993 and 2007 (compared with mean growth of 2.4 percent) across 17 advanced economies in Europe. This represented 16 percent of labor productivity growth during the period (Graetz and Michaels 2018). Similarly, survey data from 124 automotive manufacturers in Europe show that 3D printing increased the reliability and speed with which firms can fulfill orders, while case studies estimate that the IoT reduces costs, on average, by 18 percent for industrial adopters (Delic et al. 2019). During the COVID-19 pandemic, Siemens used 3D printing to increase the availability of face masks and medical components needed in the fight against the pandemic. Industrial automation has enabled the reshoring of some manufacturing to high-income economies. Foxconn, the world's largest contract electronics manufacturer best known for manufacturing Apple's iPhone, has recently announced it will spend US\$40 million at a new "smart" factory in Pennsylvania (Lewis 2014). Exploiting systematic differences across countries and industries, Hallward-Driemeier and Nayyar (2019) find that, past a threshold level, increasing robot intensity in high-income countries (HICs) is negatively associated with foreign direct investment (FDI) growth from HICs to lower middle-income countries (LMICs). However, only about one-third of country-industry pairs exceed the threshold level of robots per 1,000 employees, beyond which further automation results in a decline or deceleration in FDI growth. The efficiency of these operational technologies could also help Europe to meet another key objective of sustainability (see Box O.1).

**Operational technologies have significant potential to further boost Europe’s competitiveness, because European firms are among the leaders in their use and creation.** Germany, Sweden, and Denmark, at 22, 20, and 15 robots per 1,000 workers engaged, respectively, had the highest intensity of robot use in 2016. Other countries of the EU14, along with the United States, comprised the top 10 globally. Among the smaller more recent EU countries, Slovenia, the Slovak Republic, the Czech Republic, Hungary and Poland were also characterized by a high intensity of robot use (Figure O.13). At 10 robots per 1,000 workers engaged, Slovenia’s intensity of robot use was five times that of China in 2016. European industrial companies have an enormous installed base of machines whose data they can use in IoT platforms. For example, ThyssenKrupp, a manufacturer of elevator and escalator equipment, has connected its installed base of about 180,000 units to its platform “MAX”. The analysis of these data on equipment usage reduced downtime by about 50 percent and saved costs by optimizing maintenance intervals (Fraunhofer 2019). Globally, many of the main robot producers are in Europe too. These include three each in Denmark and Switzerland, and six in Germany, compared with six in Japan and only one supplier in the United States (Leigh and Kraft 2018).

**FIGURE O.13** EU14 countries have among the highest intensity of robot use in the world (robots per 1,000 workers), 2016

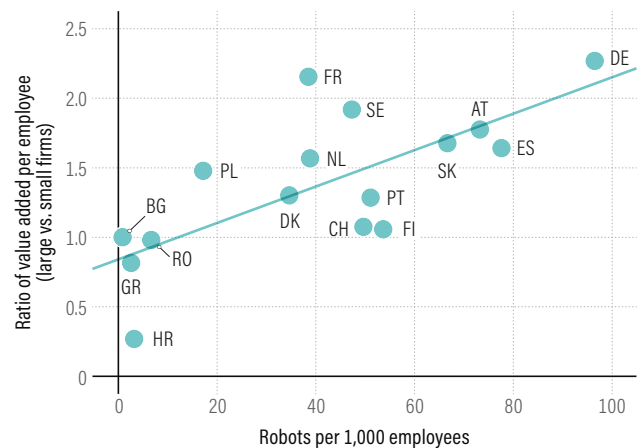


Source: Authors’ calculations, based on the International Federation of Robotics and the World Input-Output Database.

**But operational technologies tend to weaken market inclusion.** In motor vehicle manufacturing, for example, where this technology is most widespread, countries with a higher intensity of robot use are also characterized by a larger gap in labor productivity between large and small firms (Figure O.14). For example, labor productivity in large firms is more than double that of small firms in Germany, where the intensity of automation is around 100 robots per 1,000 workers. In contrast, labor productivity in large and small firms is about the same in Greece, where the corresponding intensity of robot use is close to zero. This result is consistent with the finding that, much like other forms of physical capital, the installation of robots entails high fixed costs that are likely to benefit larger enterprises. Contrary to expectations, scale matters for 3D printing too. Among the EU14 countries where the technology is most widespread, namely, Finland, Belgium, the United Kingdom, the Netherlands, and Germany, about 5 percent of all firms used 3D printing in 2018 compared with 15 percent of large firms. The use of operational technologies is also associated with a higher capital intensity in production (Figure O.15).

**FIGURE O.14** The intensity of robot use is associated with a productivity gap between large and small firms in the transportation equipment sector, 2016

Robots per 1,000 employees and the ratio of value added per worker in large vs small firms, 2016



Source: Authors’ calculations, based on Eurostat.

**FIGURE O.15** The intensity of robot use is associated with higher capital intensity in production, 2016

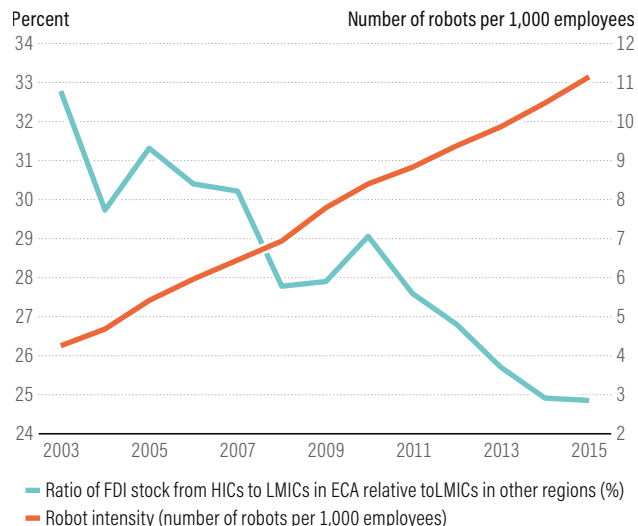
Robots per 1,000 employees and capital investment per worker, ratio between most (motor vehicles) and least technology-intensive sectors (apparel), 2016



Source: Authors' calculations, based on Eurostat.

**FIGURE O.16** Robots slowed down offshoring to Eastern Europe

Robots per 1,000 employees among HICs in ECA and the ratio of FDI stock from HICs in ECA to LMICs in ECA relative to LMICs in other regions (2004 - 15)



Source: Background paper by Hallward-Driemeier and Nayyar (2019).

**Operational technologies also inhibit convergence by concentrating production in established hubs.**

There is new evidence that industrial automation in European high-income countries (HICs) has reduced offshoring to lower-wage countries in the region (Figure O.16). This indicates that smaller EU13 countries, such as the Czech Republic, the Slovak Republic and Slovenia, are perhaps not automating enough to compensate for rising wages relative to Asia. To illustrate, the production of hearing aids, which are almost entirely 3D printed, has not shifted closer to consumers. The early innovators in Europe, such as Denmark and Switzerland, remain the major producers and account for 22 percent of world exports of hearing aids. Some middle-income economies have also substantially increased their market shares between 1995 and 2015, but these include China, Mexico and Vietnam, and exclude countries in Eastern and Central Europe (Freund, Mulabdic and Ruta 2019). In fact, Adidas announced in late 2019 that its “Speedfactories” in Ansbach in Germany and Atlanta in the United States—which use computerized knitting, robotic cutting, and 3D printing to produce athletic footwear—will be moved to China and Vietnam, where 90 percent of Adidas’ suppliers are currently located. The technology creators in Europe also remain concentrated. For example, while Germany accounts for about half of the top 20 EU regions with respect to their future potential in developing operational technologies (Boschma and Balland 2019), the Piedmont and Lombardy regions account for almost 60 percent of Italian firms producing autonomous robots (Estolatan et al. 2018).

**Taken together, these findings show that Europe faces a challenging digital dilemma.** On the one hand, in those technologies where the potential for inclusion and convergence is greatest, European firms are not sufficiently competitive. On the other hand, where European firms are competitive, new opportunities are more concentrated in larger firms and leading regions. But distinguishing across types of technology also highlights the pathway to achieving Europe’s three goals, by identifying where there are synergies and ways to manage the trade-offs.

**The COVID-19 pandemic creates new challenges for Europe’s triple objective.** As the COVID-19 outbreak quickly evolves from a health emergency to a full-blown economic crisis, firms and workers in the private sector are bearing the pandemic’s economic brunt (World Bank 2020). What it means to be competitive when workers and customers must respect social distancing requires different responses by sectors. The impact is being felt across a wide range of services, but also for manufacturing, particularly those businesses in value chains that are being disrupted by trade and slowdowns in other locations (Dingel and Neiman 2020; Avdiu and Nayyar 2020). There are also implications for market inclusion. Liquidity is expectedly more problematic

for micro and small businesses, many of which operate in “shutdown” sectors such as traditional food markets, restaurants, bars, and personal services such as fitness centers and hairdressers. Similarly, the pattern of potential job losses during the COVID-19 outbreak is likely to disproportionately affect unskilled labor. For example, occupations that are less amenable to home-based work and therefore at higher risk of layoffs are largely concentrated among lower wage deciles (Avdiu and Nayyar 2020). This includes personal care, food services, and production jobs. There may also be implications for geographic convergence if industries that are most affected are concentrated in certain regions of a country, e.g., travel destinations or manufacturing hubs.

**As governments respond with a range of financial support programs, the use of digital technologies can be a useful complement to “to keep the lights on”.** While timely financial support that limits firm bankruptcies and prevents widespread layoffs is key in the short run, digital technologies can also help firms to better adjust to the COVID-19 shock. The response to the COVID-19 pandemic and economic crisis underscore the potential for more inclusive outcomes across all three types of technology (see Box O.2).

### BOX O.2 Europe 4.0 — Even more important during a global pandemic

The COVID-19 crisis underscores the importance of the digital agenda. New technologies are making it possible for work to continue for many workers, thus reducing the extent of the supply shock as well as the demand shock as these remote workers are still getting paid. This amount of remote work would have been much for difficult to achieve a decade earlier when world was just recovering from the Global Financial Crisis. Transactional technologies are enabling many services to be performed virtually — or to coordinate the sale and delivery of goods in ways that limit in-person interactions. Restaurants, for example, can continue to operate through digital platforms that enable online ordering and home delivery of food. Similarly, online fintech platforms could facilitate supply-chain finance to SMEs by reverse-factoring transactions.<sup>a</sup> While several services where transactional technologies have been key enablers are also on lockdown, e.g. ride sharing and accommodation sharing, countries and regions with better virtual links are able to sustain more lockdowns with less economic pain.

Informational technologies offer new potential in the public health sphere, from using cell phone data to understand case patterns and compliance with stay-at-home orders, to using AI to track cases and effective treatments as well as broader economic disruptions. There are clearly privacy concerns associated with these approaches, but aggregated information can still be useful for public health officials; it is too early to tell how willing individuals may be to consent to being part of

tracing apps. Safeguards for how data would be used will be important in ensuring trust in the system and alignment with important societal goals.

For operational technologies, the smart automation also enables more production with generally greater distancing of workers. Information on potential disruptions in supply chains can now be communicated earlier which makes it possible to adjust accordingly. While there is greater talk of strategic autonomy in the manufacture of necessities (from medical protective and testing equipment to food), wholesale reshoring is unlikely as the efficiency gains for global value chain production systems remain high. Some more diversification of sources may occur, some of the patterns of automation and reshoring discussed in Chapter 5 are likely to accelerate.

How will the COVID-19 crisis impact Europe’s social and economic goals of completeness, inclusion and convergence? In the immediate run, the importance of inclusion of firms, especially SMEs, and ensuring lagging regions access to the benefits of digital technology will be a political and social priority. This crisis response will include many more instruments than just supporting the digital agenda, but it is an important dimension. Over time as countries move to crisis recovery, competitiveness is likely to become a higher priority. The agenda laid out here of how to foster greater digital technology adoption with all three goals in mind is even more relevant than before the crisis.

Source: World Bank ‘Supporting Firms’ crisis response note, April 2020.

a. When a financial institution interposes itself between a company and its suppliers and commits to pay the company’s invoices to the suppliers at an accelerated rate in exchange for a discount

## ADDRESSING THE DIGITAL DILEMMA TO ATTAIN EUROPE 4.0




**Policy makers can address Europe’s digital dilemma by scaling markets, shaping the use of data for commercial uses, and smoothing technology adoption.** First, scaling up markets would help to expand the use of digital technologies that reinforce market inclusion and convergence. Second, in addressing new challenges introduced by big data in ways that safeguard European values, updating competition and data privacy

policies will shape the balance between competitiveness and inclusion. Third, speeding up and smoothing the wider diffusion and adoption of technologies that tend to concentrate benefits in larger firms and leading regions will share the productivity benefits of these technologies more widely.

**Differentiating by technology, these priorities become clearer.** The focus on scaling markets is the priority for transactional technologies, where the ability to be competitive is still constrained. The regulatory debates on the use of data and how best to respond to the new types of market dominance that big data brings are of first-order importance for informational technologies. Meanwhile, the need to diffuse opportunities through enabling wider adoption of technology is particularly relevant for operational technologies.

**The policy recommendations are also mutually reinforcing across technologies.** Scaling markets will matter for informational technologies too. With earlier waves sharing some of the same potential as transactional technologies in terms of geographic convergence, the same recommendations to raise competitiveness could bring inclusion and convergence benefits here too. However, newer informational technologies have consequences similar to operational technologies. So, as with operational technologies, more needs to be done to support the diffusion of these technologies across a wider set of firms. And the regulation of data will matter too, of course, for transactional platforms, and increasingly for operational technologies as the IoT expands. There is a priority for each technology, but the package provides a whole that supports all technologies' contributions to Europe's triple objectives.

**FIGURE 0.17** Addressing the digital dilemmas across digital technologies

	 <b>Transactional technologies</b>	 <b>Informational technologies</b>	 <b>Operational technologies</b>
<b>Digital dilemmas</b>	Contributes to all three goals, but limited competitiveness means that potential is only partially realized	European firms show more promise, but new opportunities are more concentrated	European firms are among leaders, but technologies favor large firms and increasingly concentrate production
<b>Policy directions</b>	Scaling markets	Shaping commercial use of data	Smoothing adoption in MSMEs and lagging regions

Source: Europe 4.0 team.

**This report's policy recommendations distinguish between policies and investment allocations made at the level of the EU, and those at that national level or sub-national levels.** For member states of the EU, the agenda requires more coordination and alignment on priorities, but also provides additional instruments for achieving the goals. For non-member states, the issues discussed would need to be addressed at the national level, keeping in mind their consistency with EU rules and regulations.

## Transactional technologies: Scale markets to realize the potential for market inclusion and convergence

**Scaling markets in Europe is central to expanding the use of transactional technologies, and thereby realizing their potential for inclusion and convergence.** Transactional technologies have the potential to connect more smaller firms to larger markets, while expanding digital exchanges such that geography should matter less. The challenge is that uptake by firms and consumers is not widespread, and Europe is not creating

many leading firms in this space. Exploiting network effects is what benefits users on both sides of the market that the digital platforms help to match. Unless the constraints to market scale are lifted, these technologies cannot really take off. There are also other complementary factors necessary for users to take up these types of transactional technologies, including logistics and trust in the system.

## EU level: Scaling European markets

**At the level of the EU, achieving scale requires completing the digital single market.** For non-member states, it involves expanding digital trade with the larger EU market. The outstanding issues are already well recognized. These include the continued limitations on making sites truly accessible across international boundaries, and the continued restrictions on the portability of copyrighted digital material that limits sales or the transfer of some property across borders.

**It also requires addressing the remaining barriers in the single market, particularly for services.** In addition to digital markets, there are several complementary factors that determine whether efficiency gains are realized. Several are based on ways in which the single market, particularly in services, itself is not complete. One example is the “Amazon Paradox”, where it both costs more and takes longer for e-commerce across countries in Europe than it does across states in the United States; Amazon Marketplace is profitable in North America but runs at a loss in Europe. When the cost of sending packages across countries can be 370 percent more than the cost of sending the same package domestically, the barriers to achieving scale are real (Van Der Merel, 2019). In Europe’s many small economies, the reliance on a network of national postal systems can introduce delays and higher costs. The potential applications are also limited if there are restrictions on the digital delivery of many services across borders within the EU, particularly professional services. Such applications would be particularly beneficial for lagging regions.

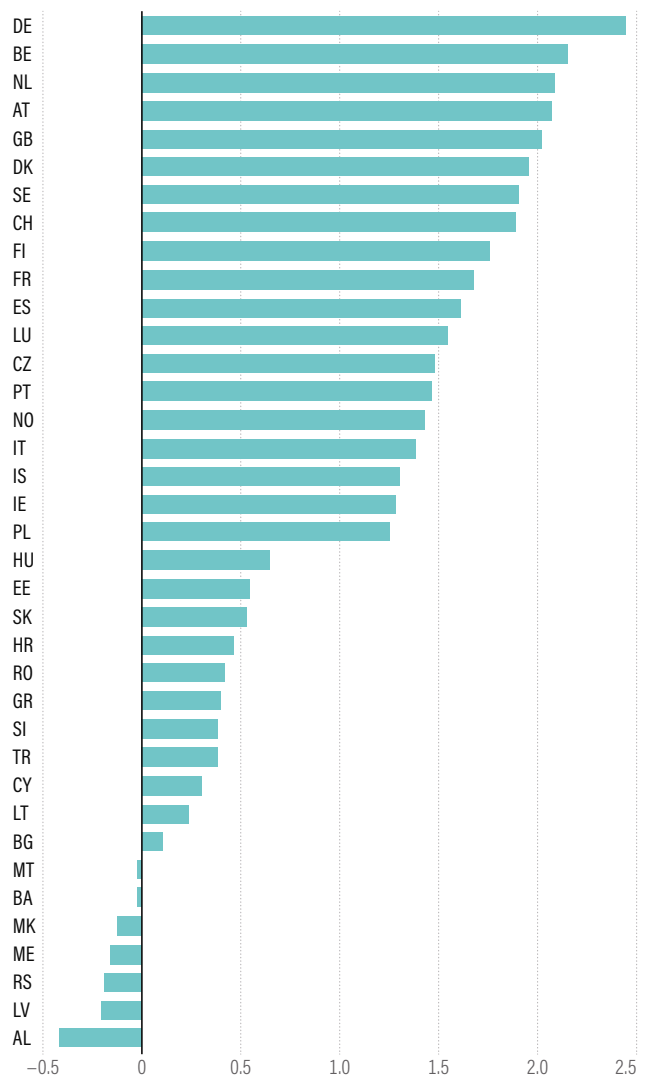
## National and sub-national levels: address “analog complements” to enable wider digital diffusion

**The ability to trade within Europe is also affected by regulatory differences at the national level.** Product regulations and taxation can limit trade across borders in practice by raising costs of compliance (Van Der Merel, 2017). Unevenness in the implementation of single market regulations can also raise the level of uncertainty or costs for firms seeking to work across borders within the EU.

**At the sub-national level, the absence of complementary factors could hinder the dissemination of transaction technologies—access to broadband is not enough.** The low uptake of e-commerce in many European regions underscores the reality that the diffusion of even basic transactional technologies is not automatic. Access to broadband

**FIGURE 0.18** Logistics competence

Normalized LPI scores (global average=0; standard deviation=1)



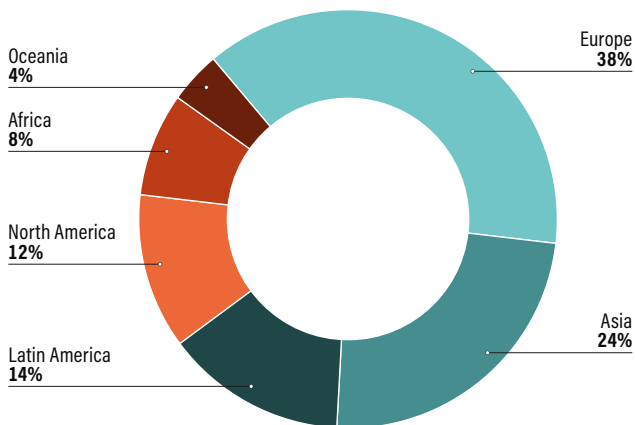
Source: World Bank Logistics Performance Index, 2018



is not sufficient. Other constraints include gaps in the enforcement of regulations and tax where the informal economy may still be preferred to having transactions with digital footprints (World Bank, 2016). Users' digital literacy and the availability of digital skills matters as well, although the skills necessary to use such technologies is fairly low. Together, these 'analog complements' matter in determining the extent to which users turn to transactional technologies which, in turn, affects how well companies themselves can be competitive and achieve larger scale.

## Informational technologies: Shaping the commercial use of data for greater market inclusion

**FIGURE 0.19** European competition authorities lead among regions in launching investigation



Source: World Bank Competition Policy Project.

**The nature of regulatory responses to the challenges posed by AI and new types of market dominance will shape the balance between competitiveness and inclusion for informational technologies.** The earlier wave of informational technologies helped contribute not only to competitiveness, but also to market inclusion. As such, the agenda to expand their use is shared in part with that of transactional technologies. However, the dynamics are changing with the growing use of big data analytics and machine learning. The network effects of platforms and the insights gained from harnessing large amounts of data are the source of efficiency gains and innovation. But these dynamics are precisely what raise new challenges to competition authorities, and to those safeguarding the value of consumer protections and data privacy within Europe (Rosotto et al., 2018). The next steps will be critical in determining how well Europe balances size, innovation and contestability of markets for entrants and SMEs (Furman et al., 2019).

### EU level: Making competition and data privacy regulations fit for purpose in the digital age

**Europe has been a global leader in its use of competition policy in the digital economy but this policy will need to be continuously updated as new risks associated with market dominance emerge.** The EU's commitment to using competition policy for the data economy is not just about providing a level playing field for European and non-European digital firms. It has recognized a number of ways in which competition policy needs to adapt to the new sources and potential uses of market dominance (Nyman et al, 2019). These include: safeguarding against self-preferencing on platforms and search results; pricing policies, including dynamic pricing over time, that can discriminate across consumers; updating approaches to mergers and acquisitions (e.g., setting thresholds for review based on the size of the deal and not just on the level of turnover of the firm being acquired; who bears the burden of proof of whether consumers would be harmed); the need to speed up times for review and enforcement; updating the relevant types of remedies available; and the need to review algorithms for their impacts on different groups of vulnerable consumers (Cremer et al, 2019). The EU needs to continue taking its mandate seriously: to make markets contestable, to encourage entrants, and to deter large players from abusing their dominant position in pricing, packaging products and services, and in marketing and financing.

**The EU is also poised to lead on data regulations to encourage the sharing of non-personal commercial data that could be a source of competitiveness and inclusion.** If data are an increasingly important source of value added, making data available to more firms could support both inclusion and innovation (Bauer et al,

2016; Van der Marel, 2019). But the distinction between personal and non-personal data is likely to become increasingly blurred with the proliferation of sensors and facial recognition software. As such, data privacy regulations will be critical in how these opportunities develop.

**Data privacy regulations of personal data are motivated by safeguarding consumers and citizens, but their impacts on innovation and inclusion need to be considered too.** The EU and the governments of its member states are committed to ensuring that data and AI are used for human-centric purposes. The restrictions are on personal data rather than commercial or non-personal data. However, the regulations introduce costs of compliance. These are proportionally higher for smaller firms, having the unintended consequence of working against inclusion (Chivot and Castro, 2019; Jian and Wagner, 2018). There are also questions about the abilities to innovate if data cannot be repurposed, or if there are penalties for sharing personal data. Encouraging data portability and interoperability standards should provide greater opportunities for SMEs and entrants, thereby helping support innovation — and market inclusion.

**The extent to which Europe values privacy can influence global standards depending on whether ‘privacy by design’ can be a source of comparative advantage.** Europe’s approach is already shaping global markets, as its trade and investment partners have to comply and adhere to EU regulations (Mattoo and Meltzer). Reinforcing this, if Europe can build more and larger firms that comply with the various ‘privacy-by-design’ features, there is an opportunity to set global standards on these issues that Europeans care about in other markets. Given reactions to scandals on how data have been used to manipulate elections or to target willingness to pay, non-European consumers’ interest in privacy and the trusted use of data is likely to grow.

### National and sub-national levels: Helping informational technology startups

**To support both competitiveness and inclusion, more can be done to support the startup ecosystem for digital businesses.** Unlike traditional startups, new informational (as well as digital transactional) business models have more intangible assets, which means there is limited collateral to use to secure financing. Given the time to generate network effects, such firms may also need significant funding that can only be paid back with lags. A popular form of venture capital that helps minimize labor costs upfront and shares the risks and upside potential is the use of stock-options. However, these cannot easily be transferred across borders given that financial regulation varies at the country level. In addition, the initial public offering (IPO) regulations that have a ‘one-size-fits-all’ model with heavy administrative requirements are not well suited for innovative businesses that have different sizes and capital needs. Different regulatory measures and taxation rates can also tilt some firms’ interest to incorporate outside Europe (European IPO Report, 2015). The NASDAQ has benefited from listing several firms with European founders. Lastly, new waves of informational technologies are more skill intensive. Doing more to attract and retain skilled workers would enable more firms in more locations to compete. Supporting more new informational firms to scale up in Europe could support all three of its economic goals.

### Operational Technologies: Smooth technology adoption to enable opportunities for greater convergence and market inclusion

**Accelerating the diffusion of operational technologies is necessary for the productivity benefits to be shared widely.** Given Europe’s competitiveness in operational technologies, the agenda is to continue building on this source of strength, while also working to enable more firms and locations to support its use to counter the concentration of its benefits. Europe’s strength in operational technologies is reflected in the large share of R&D that is performed in these technologies. The large bulk of this R&D is carried out by a relatively small number of large firms. More applied R&D by a wider set of firms would help to expand who can absorb and use the more productive means of production.



**New operational technologies are drawing increasingly on transactional and informational technologies in ways that could reinforce the potential for greater market inclusion.** Much of the attention to date on data platforms has been on B2C companies where Europe is relatively less competitive. However, the expansion of industrial IoT and B2B platforms could be a growing source of competitiveness for European firms that are leaders in operational technologies. Proposals to facilitate the sharing of commercial, non-personal data could reinforce this, assuming it is done in ways that are aligned with competition principles (i.e., is not done to facilitate collusion). The building of larger pools of data could allow for more innovation and a wider application of operational technologies in areas such as the management of building complexes, or utility or infrastructure systems. However, the impacts on market inclusion and convergence would need special attention if they are likely to be achieved in practice (see Box O.3).

### **BOX O.3** How would the new EU data strategy of February 2020 address the digital dilemma?

The Commission announced on February 19, 2020 a new and ambitious data strategy. This report provides new insights into how the new strategy will help Europe reach its ambitions. On the one hand, the new strategy focuses on strengthening Europe's competitiveness. It aims to leverage Europe's strength in operational technologies, while seeking to do more with the data generated by these technologies. The push to expand industrial IoT to inform a wider set of processes, the greater sharing of commercial data and wider use of public data, as well as the development of more B2B platforms within manufacturing, would be harnessing elements of informational and transactional technologies to raise further the competitiveness of Europe's operational technologies. This is promising.

However, as the report makes clear, the EU's new data strategy is not likely to address growing tensions with the goals of market inclusion and geographic convergence unless complemented by additional investments and targeted policies. How the EU will move from strategic principles to regulations and investments will matter a great deal in the strategy's impact on the digital dilemma. The regulations on when and how data needs to be shared will not only be about setting standards, but will be critical in determining whether smaller firms and entrants can realistically compete and adopt these new digital technologies. It is not just about the *de jure* rules, but about their impacts in practice. Here, three empirical insights are critical for Europe to succeed:

- First, while the earlier wave of informational technologies has been contributing to market inclusion, this might not continue to be true of the latest applications. In particular, the use of big data analytics and machine learning are widening performance gaps between larger and smaller firms and between leading and catching up regions. Thus, the new uses of digital technology being supported

by this strategy may reduce rather than enhance market inclusion and convergence in practice.

- Second, while B2C can enable a wide range of firms to use the platforms, the same has not yet been demonstrated for B2B; they are more successful for large value chains where there are economies of scale than for even medium sized lead firms (Fraunhofer, 2019). So, while expanding transactional technologies could contribute to market inclusion and convergence, it might not necessarily be as true with B2B platforms.
- Third, to the extent there are digital skill and data management requirements and greater need for a conducive business environment to support the use of the underlying new technologies along these value chains, the evidence shows that smaller firms and firms in catching up regions might need more active support to be able to absorb these technologies and seize the new opportunities. Access to digital opportunity might not be enough.

The new data strategy raises the stakes and the potential of how the data economy can raise European competitiveness. The analysis presented here provides ways to help realize this potential while avoiding some of the trade-offs. To make this data strategy feasible, more still needs to be done to complete the Digital Single Market to enable data to flow and be used in practice (see Chapter 6). To be inclusive of smaller firms and new entrants and to support regional convergence, both the rules (discussed in Chapter 7) and the efforts to support a wider deployment and adoption of these technologies (discussed in Chapter 8) will be needed. This augmented approach would then reinforce the potential to attain all three objectives – and strengthen the potential for Europe's approach to data itself to be a source of comparative advantage.

*Source: Europe's Digital Strategy, February 19, 2020, and Europe 4.0 team*

## **EU level: Balance funds for research with funds for technology diffusion**

**At the EU level, this means the allocation of research and regional development funds should balance innovation at the frontier with supporting adoption among SMEs and lagging regions.** The evidence shows that new areas of excellence can emerge; Poland has two and the Czech Republic has one of the top 20 innovation hubs in the EU. Even countries in the Balkans show areas of promise in particular types of data-driven technologies (see Box O.4). But attempts to leapfrog into areas with limited expertise or a poor

track record using frontier technologies rarely succeed. Building on existing capabilities is more likely to be successful. Two other criteria are encouraging research networks and supporting applied R&D in areas that have links to local markets (Balland and Boschma, 2019; Muscio and Ciffolilli, 2019). This approach is much more likely to develop connected centers of excellence that serve as hubs rather than islands that are isolated from their local economies. Conducting reviews of the efficiency and effectiveness of spending could be used to further improve the allocation of these funds.

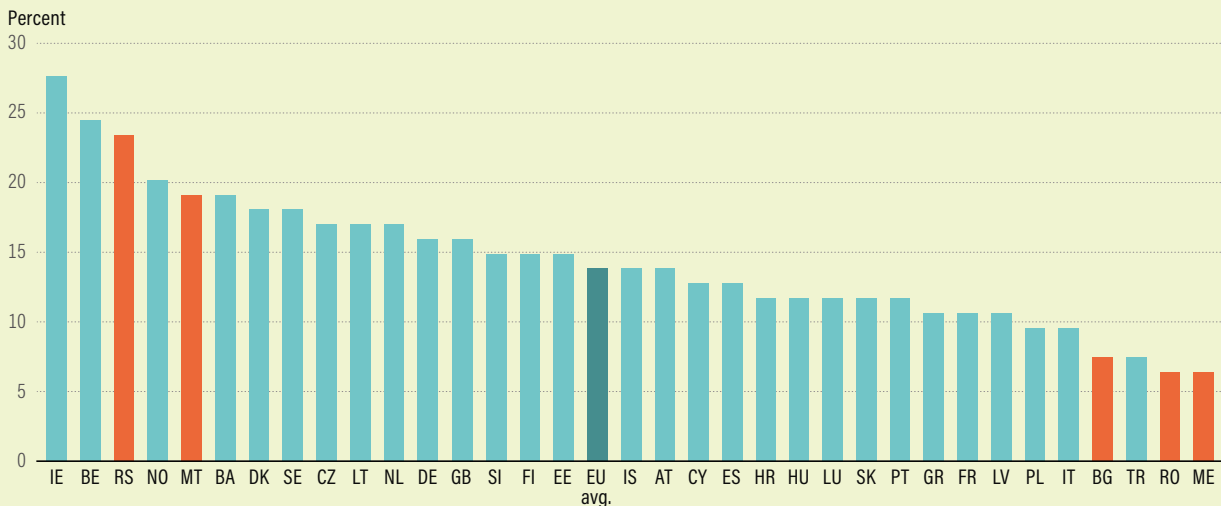
**BOX 0.4** The Western Balkans is on par in data-driven technologies with Southern and Southeast Europe

As expected, no Balkan economy has become a leader in new digital technologies. However, while none of these countries is strong across all digital technologies, some are strong in a few of them and are investing to build on these emerging strengths.

EU membership on its own has not enabled countries such as Romania and Bulgaria to significantly scale up their use of digital technologies. Fewer than 10 percent of firms in Romania and Bulgaria meet even

a minimum threshold of selling online (see figure below). But while still an EU candidate country, Serbia outperforms many EU14 countries in the use of online sales. Western Balkan countries of Serbia and Bosnia and Herzegovina are in the top countries in the share of firms that use a B2B or B2C website or app to sell online in Europe. Meanwhile, Romania, Bulgaria, Montenegro, and North Macedonia constitute four of the bottom five countries in terms of low use of a B2C website or app for online selling.

**FIGURE BO.4.1** The share of enterprises that use a B2C website or app to sell online in Europe, 2018



Source: Eurostat and OECD.  
 Note: The orange bars are countries in the Western Balkans.

However, there are also potential clusters of excellence in the Balkans, which data on patents confirm. Serbia's Novi Sad and Romania's Cluj have nascent digital clusters. Bulgaria's Yugozapaden region demonstrates considerable potential in augmented reality (top 10 of all European regions), as well as capabilities in cybersecurity and some operational technologies

such as additive manufacturing and autonomous vehicles. Several regions in Romania also demonstrate capabilities in cybersecurity and operational technologies. North Macedonia is investing in Augmented Reality, and Montenegro shows a moderate advantage in Simulation, as well as Augmented Reality, based on the Horizon 2020 funding it has received.




Source: Europe 4.0 team; Balland & Boschma background paper for Europe 4.0 (2019).

**National and sub-national levels: Supporting firm capabilities to absorb new technologies**

**The focus at the national and sub-national levels should be to support firms' capabilities to accelerate technology diffusion.** This includes supporting hubs/sectors of relative strength in the local economy and on developing new applications for general purpose technologies (GPTs) in those traditional sectors. It also

means working with firms to strengthen their capabilities to absorb technologies and manage the internal change processes to use it successfully (Cirera and Maloney, 2017). More can also be done to attract the skilled workers needed for many of the newer technologies.

**FIGURE 0.20** A policy agenda for Europe 4.0

	 <b>Transactional technologies</b>	 <b>Informational technologies</b>	 <b>Operational technologies</b>
<b>Policy directions</b>	Scaling markets	Sharing commercial use of data	Smoothing adoption in MSMEs and lagging regions
EU	Complete digital single market and support trade in services	Making competition and data-privacy regulations fit for purpose in digital economy	Allocation of R&D and regional funds to build capabilities and links to markets
<b>Policy priorities</b>	National governments	Start-up ecosystems Venture capital markets Digital skills	Support applied R&D, research-firm links
Subnational governments	"Last-mile" infrastructure, enforcement	Innovation hubs Expand links with local firms and markets	Strengthen firms and governments capabilities to support adoption

Source: Europe 4.0 team.

## ADDRESSING THE DIGITAL DILEMMA REQUIRES CAPTURING SYNERGIES AND MANAGING TRADE-OFFS

**The framing of the policy debates will determine whether Europe’s three objectives are mutually incompatible or reinforcing in the digital economy.** This depends, in part, on different visions of ‘competitiveness’: whether having giants in global markets is the goal, or having a vibrant digital economy is the ultimate measure of success; whether the emphasis is on creating new technologies, or widely disseminating them; and on whether opportunities are expected to diffuse on their own, or whether adoption is itself a part of the agenda to support market inclusion and convergence. And, if Europe wants its values to have a wider influence internationally, which of these visions is the more effective approach matters all the more.

**Concerns about the lack of European global tech champions puts the focus on a narrow definition of success that risks setting up policy prescriptions where goals of size are pitted against the goals of market inclusion and convergence.** It would tilt rules toward big firms (e.g., competition policy that allows monopolies, does not safeguard against ‘buy and kill’ acquisitions, etc.) and allocate investments to large incumbents in their existing production locations.

**Europe’s value-driven policies offer a different path to address the digital dilemma and embrace Europe 4.0.** Distinguishing between technologies is important as they vary in their contribution to Europe’s triple objectives of economic competitiveness, market inclusion, and geographic convergence. This report discusses policy priorities in terms of how they address potential tensions or trade-offs between these goals within a given type of technology. But the recommendations are mutually reinforcing across technologies. If taken together, the approach emphasizes synergies that will make Europe better positioned to be competitive and expand opportunities across firms and locations—and, in so doing, make it more likely that the most successful companies can come from Europe and thrive.

## Note

1. In this report, “Europe” refers to the continent of Europe. In some cases the focus may be on European Union countries, in which case this is noted. In comparing sets of countries within the continent, distinctions are made between the ‘EU14’ (the original 15 countries that joined before 1995 minus the United Kingdom, i.e. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, and Sweden), the ‘EU13’ (the newer member states that have joined since 2004,

i.e. Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovenia and Slovakia), the candidate countries (Turkey, North Macedonia, Montenegro, Serbia and Albania, and also Kosovo and Bosnia and Herzegovina); and other non-member states Norway, Iceland and Switzerland and the United Kingdom, which will leave the EU at the end of 2020. When talking about policy approaches, the report focuses on the European Union as well as individual country level policies.

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# PART I

CHAPTER 1  
**Europe's Triple Objective  
in a Time of Technological Change**

CHAPTER 2  
**The Framework:  
Understanding the Economic Effects  
of Digital Technologies**

# INTRODUCTION TO PART I

Part I of this report provides the context and a framework for understanding the economic effects of technological change in Europe, and why Europe faces a ‘digital dilemma’. Divided into two chapters, Chapter 1 discusses what is at stake for Europe when considering the opportunities and challenges that new technology can bring based on Europe’s triple objectives of economic competitiveness, firm inclusion, and geographic convergence in access to opportunities. Chapter 2 distinguishes how different types of digital technologies vary in whether they diffuse or concentrate economic opportunities. It provides a simple framework to analyze the ways in which different technologies may make it easier or harder to meet these three objectives.

- Chapter 1 lays out the context of the report in three dimensions. First, it looks at some of the broad lessons of technological change, while emphasizing the things that are different this time—change is coming faster, and with artificial intelligence, more is at stake. Second, it looks at the deeper underlying objectives that Europeans value and that technological change may make easier, or harder, to achieve. Europe’s triple objectives are not just about competitiveness, but also about ensuring economic opportunities are inclusive and open to small and medium enterprises (SMEs) and entrants, as well as accessible across locations. How well Europe is currently performing in terms of these three objectives sets the context for understanding how and whether technological change will contribute toward achieving them going forward. Lastly, the chapter lays out what a European technology agenda would need to look like in order to address Europe’s triple objectives.
- Chapter 2 proposes a simple framework for organizing an effective policy response to address changing digital technologies. The insight from this framework is that digital technologies should not be thought of as a monolithic force. Different digital technologies achieve efficiency gains through different channels and thus have different impacts on the outcomes of interest to Europe. We identify three types of technologies: The first are *transactional technologies*, which are fueled by the decline in the cost of matching demand and supply through low-cost transaction platforms. The second are *informational technologies*, which are driven by the declining cost of computing power, which has fallen so dramatically that almost everyone in Europe now has an affordable supercomputer in their pocket. It means that ever more data can be harnessed to expand and improve service delivery, including customizing services or targeting specific customers. The third are *operational technologies*, which lower costs by substituting workers with data-driven machines (e.g., smart robots, 3D printers). The framework of the report enables us to look at how each of these technologies does or does not contribute to each of Europe’s three objectives. It provides a way to better understand whether the changes underway are contributing to Europe’s ability to expand its share of the global economy and to what extent the new opportunities have been shared widely within Europe—or whether trade-offs or policy measures are needed to reduce the downside risks that some technologies bring. In laying out the hypotheses that will be tested in Part II, it seems likely that not all technologies contribute positively to all three objectives; some new sources of tension will need to be addressed in order to meet the triple objectives. Thus, the framework lays out the ways in which Europe faces this digital dilemma.



Building on the framework developed in Part I, Part II presents an in-depth empirical analysis to inform each dimension of this 3x3 framework. It demonstrates the nature of Europe's digital dilemma. Part III then looks at the policy implications for each of the three types of technologies and the choices that can resolve, rather than exacerbate, potential trade-offs across Europe's triple objectives.





## CHAPTER 1

# EUROPE'S TRIPLE OBJECTIVE IN A TIME OF TECHNOLOGICAL CHANGE

There have been many examples of technological change in the past, but the current wave of change brings with it unprecedented imperatives. The European economic model places a premium on social solidarity, and thus on including smaller firms and their workers, while the European Union (EU) places a premium on political integration, and thus on the convergence of opportunities across locations within the EU. Finding a way to remain competitive while juggling these social and political objectives has not always been easy. The central question of this report is whether the new wave of digital technologies makes this balancing act easier or more difficult.

## TECHNOLOGICAL CHANGE COMES TO EUROPE, AGAIN — BUT FASTER AND WITH MORE AT STAKE

Over the coming decade, Europe's strengths and shortcomings will be tested in ways both familiar and unprecedented. Advances in artificial intelligence, made possible by three decades of progress in information technology now coming to market, are ushering in a period of potentially revolutionary economic transformations. The two differences between previous waves of technological change and the current one is its speed—it may be twice as fast as the third industrial revolution—and, arguably, that it involves both greater upside and downside than the previous three waves. Governments across the EU will need to be both quick and creative in how they respond.

### The Adoption and Diffusion of Technology in Europe: Faster

To understand what this means for producers, consumers and policy-makers in Europe, a short survey of the history of technological progress is useful. The current wave of change is referred to as the 'fourth industrial revolution', based on four waves of general purpose technologies (GPTs) since the 1800s. GPTs are best described as "changes that transform both household life and the ways in which firms conduct business" (Jovanovic and

Rousseau, 2005). The four most important GPTs of the past two centuries have been mechanization, electric power, computerization, and now the use of data to link virtual and physical worlds. Each GPT led to waves of complementary innovations and created opportunities for continued technological progress (Brynjolfsson and McAfee, 2017).

The latest GPT is the use of data to link virtual and physical worlds, powered in particular by artificial intelligence (AI) and the use of algorithms, automatic data feedback loops and machine learning (ML). While its use is still much less ubiquitous than its hype, many informed observers believe that it has the potential to fundamentally reshape economies and even change the ways in which societies function (see, for example, Autor, 2018, and Brynjolfsson and McAfee, 2017).

Over time, the pace of technological diffusion has accelerated across the world. Newer technologies have diffused much faster than older technologies (Comin and Mestieri, 2017). In particular, adoption lags—the time between when a new technology was invented and when it was adopted for production—have been noticeably shorter and accelerating in recent decades. While the average adoption lag is 42 years across all technologies and countries covered, a technology invented 10 years later is on average adopted 4.3 years faster (Comin and Hobijn, 2010). So, for example, the average adoption lag is 130 years for spindles and 110 years for steam and motor ships, but just six years for the internet.

International differences in adoption lags for any given technology have also fallen significantly. While the cross-country standard deviation was 65 years for steam and motor ships, it was only two years for personal computers and—despite its more demanding infrastructure requirements—just three years for the internet.

Naturally, what matters for economic efficiency and distribution are the productivity and employment consequences of innovation. Unsurprisingly, these are not unrelated to the speed with which a new technology is adopted and the pace of its diffusion. Faster adoption, meaning lower lags, increases the average productivity of technologies, since new technologies come with higher productivity (Comin and Mestieri, 2014). In addition, productivity growth is affected by the penetration rate of new technologies, and the share of firms or households that use the technology. As the number of units of any new technology increases in a country, productivity gains brought by the new technology benefit more workers or owners of capital. Hence, the new technology enables economy-wide productivity growth.

There is one seemingly counterintuitive finding, however. While there has been convergence in adoption lags between rich and poor countries, there has been a divergence in penetration rates, namely the length of time it takes for a large share of firms to use the technology (Comin and Mestieri, 2014). The technological preparedness of leading firms in a country is likely to drive initial adoption. To spur diffusion within an economy, however, the extent of complementary factors, such as the supporting infrastructure, skills and the regulatory environment, including competition policy, needs attention too. This distinction has important implications for policy priorities.

## With Artificial Intelligence, More Is at Stake

AI is redefining the impact of technology on Europe's economies. The ideas of computer scientists and mathematicians are radically transforming the ways in which we communicate and how we make, buy, and sell goods and services. The changes will require a rethinking of how to regulate, what to subsidize, and whom to tax. Erik Brynjolfsson, the M.I.T. professor who is an avid observer of the effects of digital technologies, says: "This is a moment of choice and opportunity. It could be the best 10 years ahead of us that we have ever had in human history or one of the worst, because we have more power than we have ever had before."

New technologies have widespread applications, from platforms that facilitate the matching of supply and demand, to smart robots that use sensors and big data to improve the efficiency of their production. But the use

of big data analytics and machine learning to improve detailed profiling and targeting of individuals is where the change attracts the most attention. The potential for improved, personalized services is very real.

However, there is an equal risk of misuse, bias, exclusion, surveillance and manipulation. Rules not only about what data can be collected, by whom and for what purposes are needed to limit the use of these technologies. The risks are not necessarily widely understood by consumers and citizens, and calls for protections vary. But today, approaches to data privacy are an increasingly important cultural value that is not widely agreed across countries and regions. How it shapes the willingness to adopt technologies will be an important determinant of its future competitiveness.

Europe has been a global innovator in addressing the new challenges of big data and the uses of AI. It introduced the General Data Protection Regulation (GDPR) in May 2018, is formulating a new AI strategy and is preparing new data services regulations. Rather than a model that largely leaves market players to determine what data are collected and for what purposes, or a model where the state has largely unfettered access to data, Europe is charting a middle course. This emphasizes the rights of individuals, and the responsibilities of firms and governments in how data are used.

### **BOX 1.1** Technology itself is helping overcome European challenges of multiple languages, cultures and regulatory systems

It is worth noting that some of the new technologies themselves help make the single market work better. Europe's single market faces challenges, such as differences in language, culture, rules and regulations. Compared with China and the United States, Europe faces more language-related barriers to trade. Narrow AI applications such as translation can radically alter the arithmetic, especially for SMEs. In the United States, for example, almost every small business that uses eBay sells internationally, compared with less than 5 percent of those that are offline (Meltzer, 2019). Even more impressive is the finding that machine translation services increased eBay-based exports to Latin America by 17.5 percent and export values by 13 percent. These numbers suggest effects equivalent to a reduction of distance by over 35 percent (Brynjolfsson et al., 2017). Imagine the implications for small businesses in Europe that trade in relatively small and fragmented markets to customers who use more than a dozen languages.

Blockchain technologies have the potential of rapidly reducing the costs of transportation of merchandise through countries that have different regulations and taxes. "Supply chains are currently managed on centralized software platforms, and the chain activities rely on human paper-and-pen processes to ensure certified products are delivered as intended to final consumers." (Padilla et al., 2019.) Distributed ledger technologies can rapidly and reliably eliminate asymmetries between physical and informational flows, and make global and regional supply chains more efficient. Value chains account for almost half of international trade today (World Bank, 2019); in Europe their importance is even greater. These advanced data technologies provide new ways to make the single market work better both for the goods and services trade.

*Source: Padilla et al., 2019 Europe 4.0 background paper.*

Given the increasing speed of technological adoption, policy responses need to be quicker—a greater challenge for the EU as a collection of member states. The time between invention and widespread use shrank from about 80 years for the steam engine to 40 years for electricity, and then to about 20 years for information technology. For AI-related technologies, it will be quicker still—and the clock has already started. As a union of member states, this poses additional challenges for coordination and places a premium on responsiveness that is more demanding than in the case of a unitary government overseeing a unitary economy. At the same time, a union has more tools, and an ability both to shape regulations and prioritize investments across a larger population and economy than its members could achieve by acting separately. It should also be noted that technology itself offers some solutions to the particular disadvantages that Europe faces as a multi-lingual, multi-cultural, multi-country union of member states (see Box 1.1).

While it makes no sense to resist technological change, shaping the nature and accessibility of new opportunities is a reasonable and important policy goal. Change is happening. Europe can aim to shape and smooth its effects, but it cannot stop or really even slow it down. To be sure, this will mean both disruption and progress. But resisting them will mean temporarily delaying the disruptive effects of new technologies, and permanently foregoing the benefits that they would

have brought. For the EU, it will also mean a rapid loss of competitiveness and global influence. Neither is consistent with European aspirations. Autor (2015) expresses this well: "Societal adjustments to earlier waves of technological advancement were neither rapid, automatic, nor cheap. But they did pay off handsomely." Understanding the extent of possible trade-offs associated with new technologies, and how policy choices could exacerbate or mitigate them, is of paramount importance. Over the past five years, the EU has already become

the leader in “regulation innovation”. But it has the assets and institutions to do a great deal more. If Europe succeeds, it may set global regulatory standards, even if it is not the world’s innovation leader.

## EUROPE’S TRIPLE OBJECTIVES OF COMPETITIVENESS, MARKET INCLUSION AND CONVERGENCE IN THE DATA ECONOMY

The agenda is not about paying attention to technological change for its own sake. Technological change is about how people relate to it and how societies adjust to it. What is of importance is what it portends for the deeper goals and values that Europeans care about. The focus of this report is on the economic dimension. Here, Europe represents a set of values that goes beyond economic competitiveness, such as the inclusion of a wide range of firms and spatial balance in access to opportunities. The critical agenda for Europe today is how to make the most of this latest wave of technological change to meet its economic goals.

Nowhere are these changes and choices that technology pose being deliberated more seriously than in Europe. The focus of this report is on how differences across new data-driven technologies are changing the ability for Europe—for better and potentially for worse—to meet its triple objectives. But first, to set the stage, it is important to understand how well Europe is already meeting its three objectives with regard to technology more broadly.

This section provides indicators of Europe’s recent performance on each of the three objectives, with additional measures of how technology may be affecting them. Identifying leading global tech firms is one measure of competitiveness. But it is a narrow one, both in terms of the coverage of firms and its lack of a forward-looking perspective. Here, broader measures of R&D spending and the relative productivity of the wider distribution of firms are important. In assessing inclusion, trends in productivity gaps between smaller and larger European firms are a key outcome. Differences in rates of innovation and technology adoption will contribute to these gaps. Market contestability and the ability for start-ups to enter and grow are another indicator of inclusion. Finally, whether firms that adopt technology are gaining or shedding workers provides another dimension on inclusion. To assess convergence, namely whether living standards in lower-income regions are growing relatively faster, is the outcome of interest. In terms of technology, the issue is whether access is available across geographic locations and whether measures of its use are comparable. Current trends in many of these indicators are not encouraging.

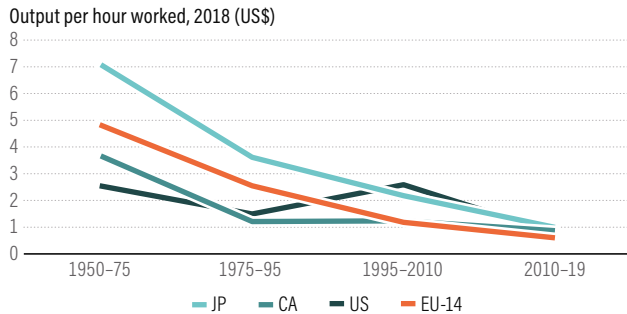
### OBJECTIVE 1: Competitiveness

Europeans care about being competitive in the new data economy. They want to have their firms recognized among the global technology leaders of the world. But they also want to ensure that many firms are able to use digital technologies to raise their productivity.

#### Competitiveness as productivity growth

Competitiveness in the data economy has as a backdrop a decline in overall productivity growth over the past 70 years. The decline in productivity growth has been widespread across high-income countries, but it has been particularly striking among European countries (Fernandez-Villaverde and Ohanian, 2018). Since the 1950s, labor productivity growth has fallen considerably in North America, Japan, and Western Europe (Figure 1.1).

**FIGURE 1.1** Labor productivity growth has fallen among the world's technology leaders



Source: Europe 4.0 team calculations, using the Conference Board's Total Economy Database.  
Note: EU = European Union.

Among Europe's leading economies, in each of the periods 1950-75, 1975-95, 1995-2010, and 2010-19, labor productivity growth fell by 50 percent.

In terms of current conditions, there are worrying signs that the European economy is becoming sluggish. After the global financial crisis, concerns about 'secular stagnation' became commonplace among advanced economies. Growth in China and India has also slowed in recent years, but these countries still account for about 40 percent of global economic growth. At the same time, growth rates have been increasing in the United States; secular stagnation seems to have become a European malady. If this continues, the gaps in economic size and living standards between the United States and the EU will keep growing (Table 1.1).

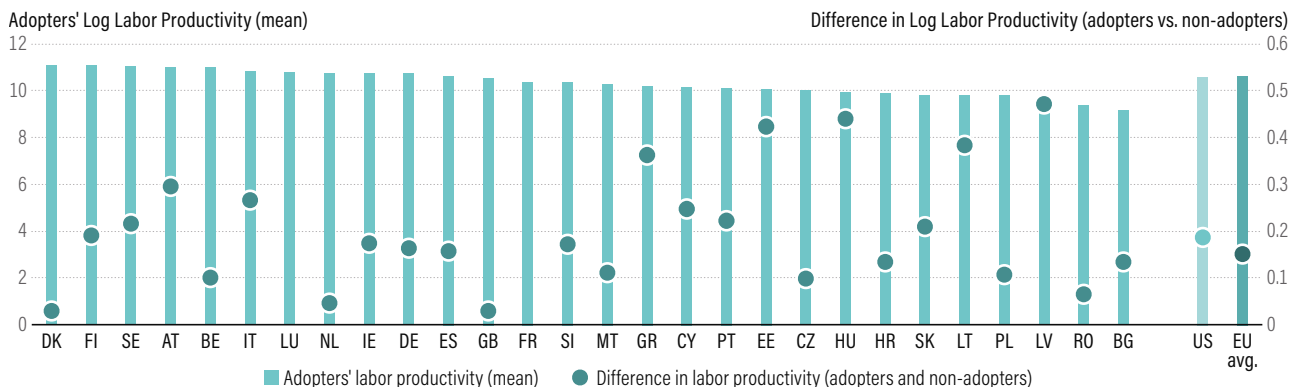
**TABLE 1.1** The EU's real GDP has doubled since 1990, even as its global share of economic activity has fallen to one fifth—as US growth has been stronger and China's has surged

	Population, 2018 (million)	World population share (%)	GDP, 2018 (US\$, trillion)	Real GDP growth, 1990-2018 (%)	World GDP share, 1990 (%)	World GDP share, 2018 (%)	GDP per capita, 2018 (US\$)
CN	1,393	18.3	13.6	3,070	1.6	15.9	9,771
EU-28	513	6.8	18.8	107	33.7	21.9	36,546
US	327	4.3	20.5	175	26.3	23.9	62,641
JP	127	1.7	5.0	105	13.8	5.8	39,287

Source: Europe 4.1 team calculations using data from the World Bank's World Development Indicators database.  
Note: EU = European Union; GDP = gross domestic product.

If productivity is the key driver to increasing GDP, then the technology agenda is critical to restoring Europe's competitiveness. Figure 1.6 shows that in nearly every European country, on average, digital firms have higher labor productivity than non-digital firms.<sup>1</sup> Furthermore, some countries with lower average productivity levels see a larger productivity bump for digital adopters (vis-à-vis non-adopters), such as in Estonia, Latvia and Hungary. Average labor productivity among firms that adopted digital technologies in the EU is also broadly comparable with the United States, with the productivity gap between adopters and non-adopters only marginally higher among the latter.

**FIGURE 1.2** Average labor productivity among digital adopters and the difference between non-adopters, 2019

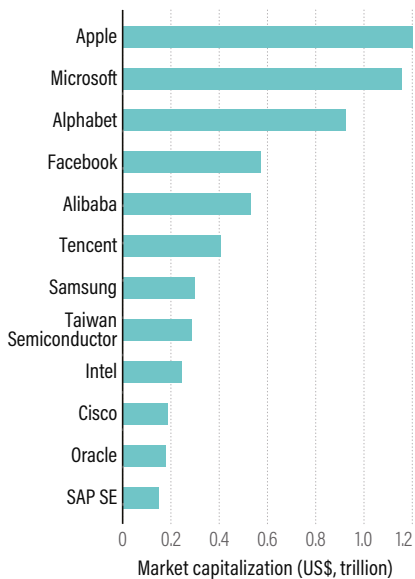


Source: Based on EIB and World Bank (forthcoming), using data from the 2019 EIBIS Survey.

## Competitiveness as frontier firms

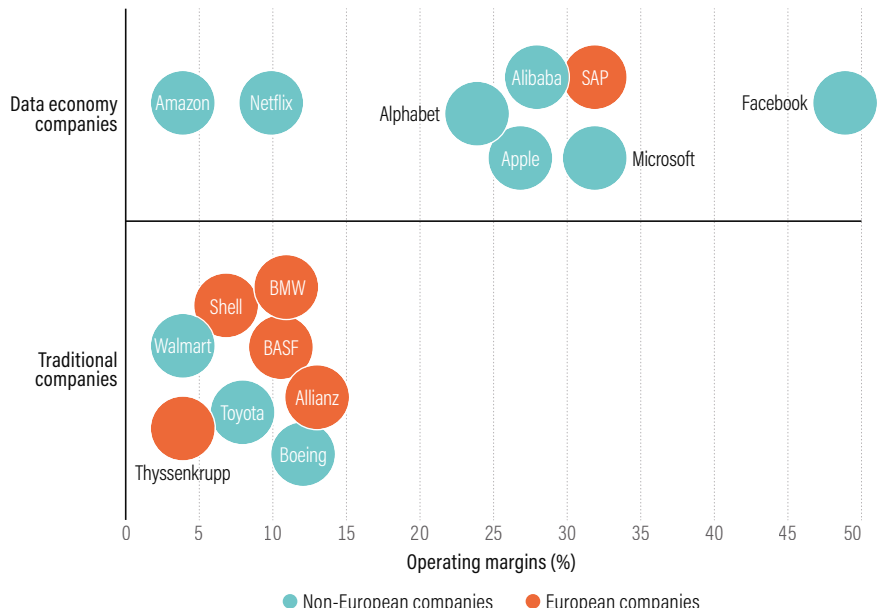
Looking at technology creation, traditional industrial firms continue to post solid rates of profitability, and Europe is among the leaders here. But even the best performers among these firms are dwarfed by the high rates of return among the largest technology companies. Among the largest global digital technology firms, the top European one is SAP, at number 12, measured in terms of profit margins (Figures 1.3 and 1.4).

**FIGURE 1.3** Europe has lost out in the first wave of digital transformation...



Source: Bloomberg.

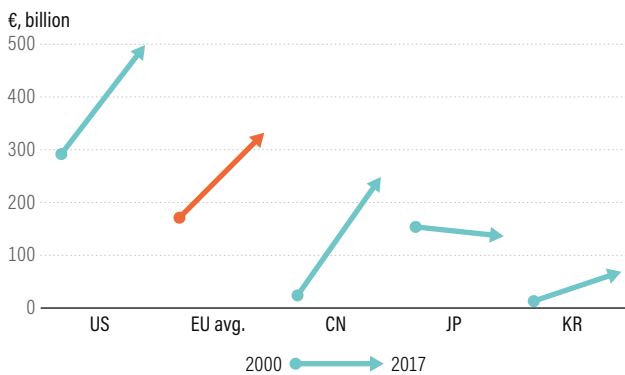
**FIGURE 1.4** ...and data companies have the highest margins



Source: Fraunhofer background paper for Europe 4.0.

Patterns in R&D also show where European firms are investing in trying to become more competitive in the future. The comparison raises some flags for the EU. In absolute amounts of R&D investment, the EU invests less than the United States, but about one-third more than China, double the amount that Japan invests, and five times more than the Rep. of Korea (Figure 1.5). However, when normalized as a percentage of GDP, the EU invests the least in R&D among this group of countries—and with little increase since 2000 (Figure 1.6).

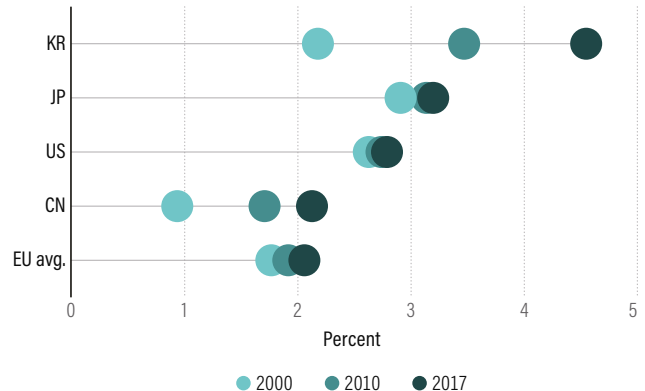
**FIGURE 1.5** R&D investment in the EU is about one-third less than in the United States



Source: Eurostat.

Note: EU = European Union; R&D = research and development.

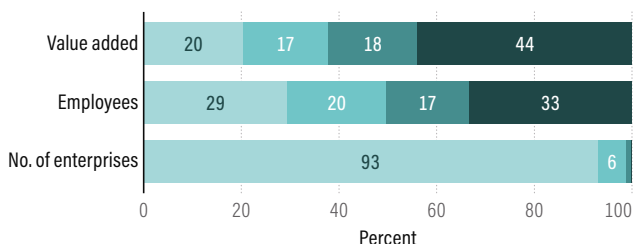
**FIGURE 1.6** Average R&D intensity is lower in the EU compared to global leaders



Source: Eurostat



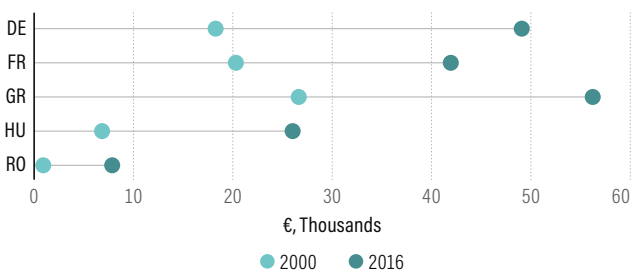
**FIGURE 1.7** SMEs are a large part of the European economy



Source: Eurostat.  
Note: SMEs = small and medium enterprises.

**FIGURE 1.8** Convergence in labor productivity between SMEs and large firms, 2000 – 16

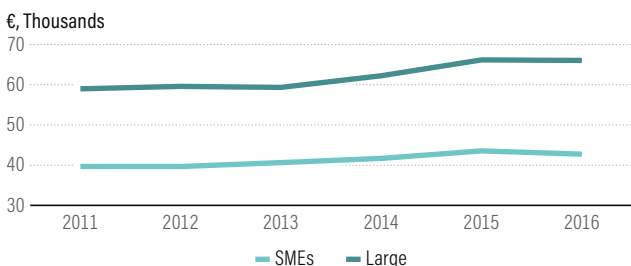
Gap in gross value added per person employed between large firms and SMEs, 2000 and 2016



Source: Authors' calculations based on Eurostat.  
Note: This chart includes firms in the manufacturing sector only; large firms are those with 250 employees or more. SMEs = small and medium enterprises.

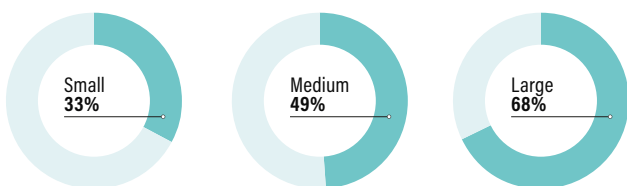
**FIGURE 1.9** Hints of widening gaps in labor productivity by firm size since 2011

Value added per persons employed



Source: Eurostat.

**FIGURE 1.10** Larger firms make more frequent process and product innovations



Source: OECD's Science, Technology, and Industry Scoreboard 2014.  
Note: Figure does not include micro enterprises.

## OBJECTIVE 2: Market Inclusion

Europeans care that the new opportunities technology brings are accessible—across firms of different sizes and ages. Inclusion, namely the ability of SMEs and new entrants to participate in the data economy, is thus a goal in its own right.

### Inclusion of SMEs

SMEs receive attention in part because they make up the overwhelming majority of European firms, representing 99.8 percent of all enterprises in the EU. They employ two-thirds of all workers in the European private sector, and account for 56 percent of the value added in the European economy (Figure 1.7).

But they also receive attention because they face greater challenges in raising their productivity and in being able to take full advantage of new opportunities. The observed differences in productivity among European firms is large and, more worryingly, growing in many countries (Figure 1.8). In 2016, workers in SMEs were only 65 percent as productive as in large firms. More disconcertingly, the productivity gap has been growing. While large firms' productivity grew by 2.3 percent in the period 2011–16, SME productivity grew by just 1.5 percent over the same period (Figure 1.9). The question is whether the adoption of data-driven technologies is likely to exacerbate this growing divide between large and small firms.

Smaller firms generally lag behind large firms in the data economy, both in terms of innovation and the adoption of digital technologies. These differences explain part of the observed productivity differences between larger and smaller firms. SMEs generally spend less on R&D than large firms; in 2016, European SMEs spent €52 billion on business R&D compared with €147 billion for large firms. Larger firms are also more likely to introduce new product and process innovations (Figure 1.10).

SMEs also lag in the adoption of basic digital technologies, such as fast broadband, having an internet presence, selling online, or utilizing cloud computing or similar online data storage services. Unsurprisingly, given the cumulative nature of technological progress, SMEs are also slower to adopt Industry 4.0 data-driven technologies, such as 3D printing, robotics, and big data analysis (Table 1.2). This is unsurprising, because basic digital technologies, particularly broadband access, are generally prerequisites for the use of more advanced technologies.



## Inclusion of entrants

In terms of dynamism – the entry and exit of firms in the economy – Europe performs well in terms of the number of start-ups created annually. New business density, defined as the number of new business registrations per 1,000 people aged 15–64, grew from 4.0 in 2011 to 4.8 in 2016 in Europe, compared with 3.3 in the United States (Shambaugh et al., 2018).

Unicorns, namely privately held start-ups with a calculated market capitalization of more than US\$1 billion, are of particular interest in showing where new ideas are coming from, and which ecosystems are enabling new successful businesses to thrive. Of the 418 firms that qualified as unicorns as of October 1, 2019, 49 are from Europe for a total of US\$104.37 billion (Table 1.3). While Europe accounts for close to one-quarter of global GDP, it has 11.7 percent of the unicorns and only 8 percent of the total market capitalization of unicorns. This suggests that Europe is under-represented among the largest of these firms.

**TABLE 1.2** Gaps in basic digital technologies between firms will make Industry 4.0 gaps even wider

Use of digital technologies by firm size, 2018

	Small and medium enterprises (%)	Large firms (%)
<b>Basic digital technologies</b>		
Fast broadband	43	75
Have a website	77	94
At least 1% of turnover from online sales	17	38
Cloud computing services	17	39
<b>14.0 Technologies</b>		
3D printing	4	13
Industrial or service robots	6	25
Big data analysis	12	25

Source: Eurostat.

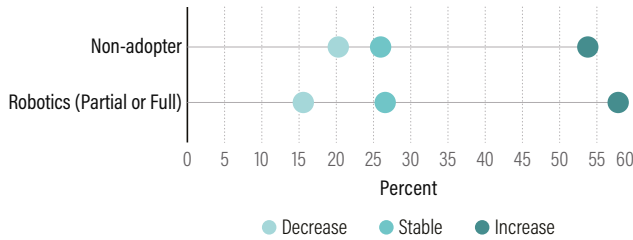
**TABLE 1.3** European unicorns are concentrated in the United Kingdom and Germany, but they are swamped by the number in the United States and China

	Total no.	Market capitalization, January 2019 (US\$, billion)		Total no.	Market capitalization, January 2019 (US\$, billion)
United States	207	632.18	Singapore	2	15.60
China	101	390.88	Sweden	2	7.07
United Kingdom	21	51.63	South Africa	2	2.58
India	18	60.12	Colombia	2	2.15
Germany	11	21.76	Hong Kong SAR, China	2	2.00
Korea, Rep.	10	31.44	Malta	1	2.50
Israel	6	7.85	Spain	1	1.40
Indonesia	5	24.40	Canada	1	1.00
Brazil	5	14.00	Luxembourg	1	1.00
Switzerland	5	11.01	Netherlands	1	1.00
France	5	6.00	Philippines	1	1.00
Australia	3	5.24	Portugal	1	1.00
Japan	3	4.10			

Source: Europe 4.0 team calculations, using data from CB Insights' Global Unicorn Club (<https://www.cbinsights.com/research-unicorn-companies>).

Note: European unicorns are highlighted in orange.

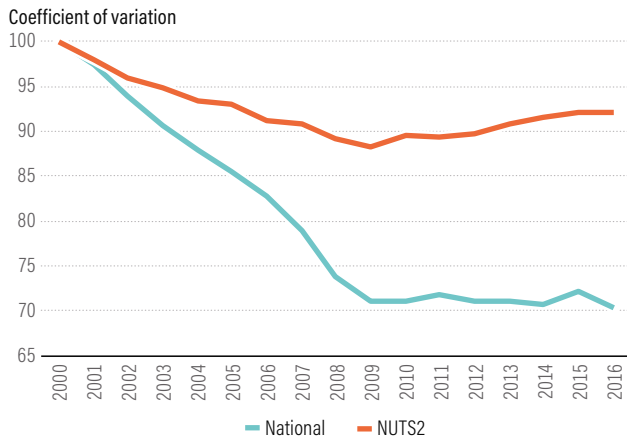
**FIGURE 1.11** Trends in employment growth over the past three years, by robot adopters, 2019



Source: EIB-WBG background paper by Cathles, Nayyar and Rückert (2020).

**FIGURE 1.12** Earlier strong convergence, i.e., smaller variation in GDP per capita across locations over time, has more recently stalled across countries in Europe, and even reversed at the NUTS2 level

Coefficient of variation of GDP per capita in PPS terms. Population weighted. (2000=100)



Source: RER.

## Inclusion of workers in upgrading firms

Technology can be labor displacing. But it can also increase the demand for new products and services and, if the demand response is big enough, generate new tasks and create new jobs. Looking at the use of robots in firms, the evidence is encouraging that adopters are more likely to hire labor than non-adopters (Figure 1.11).

## OBJECTIVE 3: Geographic Convergence

### Convergence in incomes

Europeans also care that new market opportunities are accessible and that lifestyles are relatively equal across locations. The EU was a convergence and growth machine in early 2000s. Growth supported strong convergence in GDP per capita across countries and regions, and raised living standards, particularly in new member states. Since 2010, however, convergence has slowed considerably at the national level and mildly reversed at the sub-national (NUTS2) level (Figure 1.12).

### Convergence in access to digital opportunities

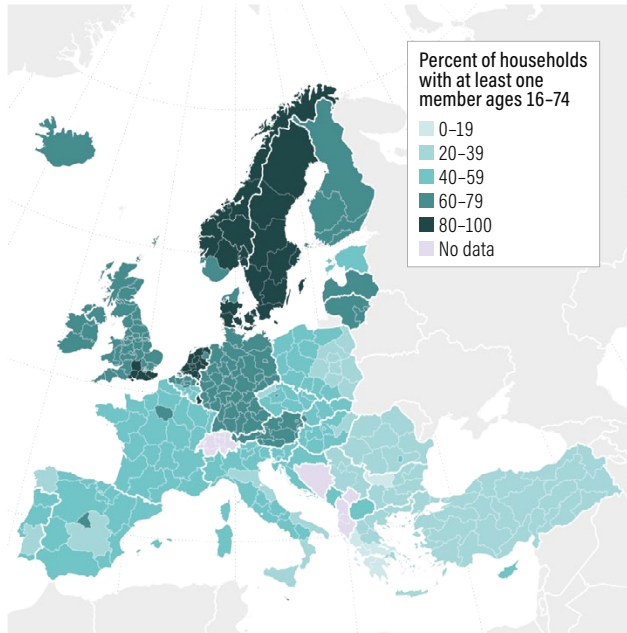
In terms of access to digital opportunities, Europe has made tremendous strides rolling out access to ICT. The expansion of broadband coverage over the past decade means that almost all firms or households can access digital technologies. However, it is clear from Map 1.1 that this has not been sufficient to deliver convergence in the use of even basic digital technologies.

The considerable variation in ecommerce outcomes across NUTS2 regions within Europe underscores that a wider set of factors matters for convergence in digital opportunities than access to broadband. Differences in complementary factors such as logistics, skills, governance and trust in the digital system are needed, and these vary geographically. It is also clear that there are significant gaps in the third industrial revolution that remain to be closed. Speed may be accelerating at the frontier, but for many regions the priority issue remains one of catching up.

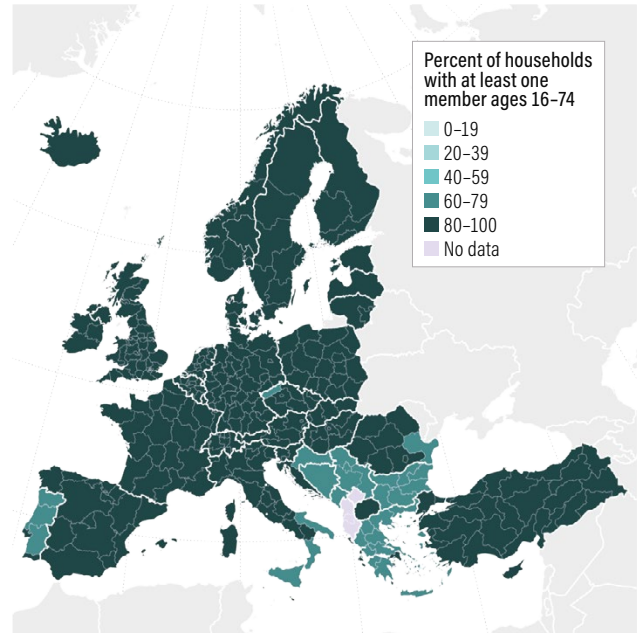
With respect to innovation, there is evidence of spatial disparities in data-driven technology creation and adoption. Innovation hubs are concentrated in Western and Northern Europe, while Southern and Eastern Europe lag behind. Even within leading countries, there is considerable concentration in certain regions (European Commission, 2019). What matters for convergence is how this then translates into diffusion, namely how well researchers and firms in other markets can access new ideas and new ways of doing things, and link into the markets and value chains that are using them.

**MAP 1.1** Convergence in access to ICT is not sufficient to enable convergence in digital outcomes

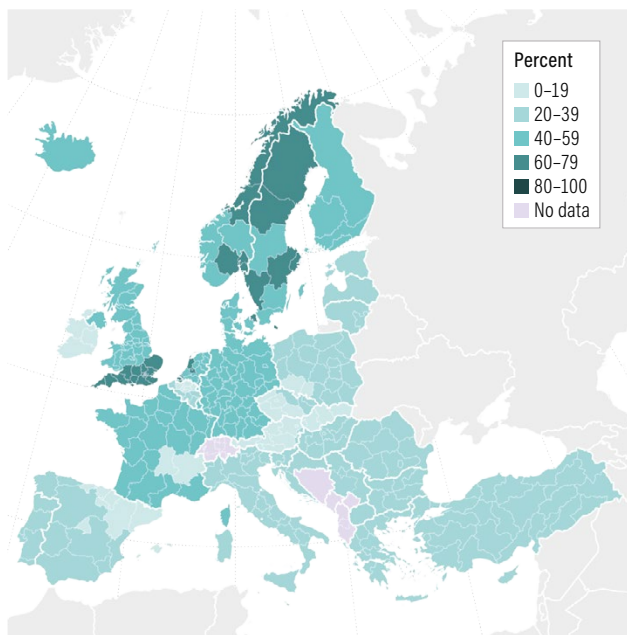
a. Households with broadband access  
1. 2008



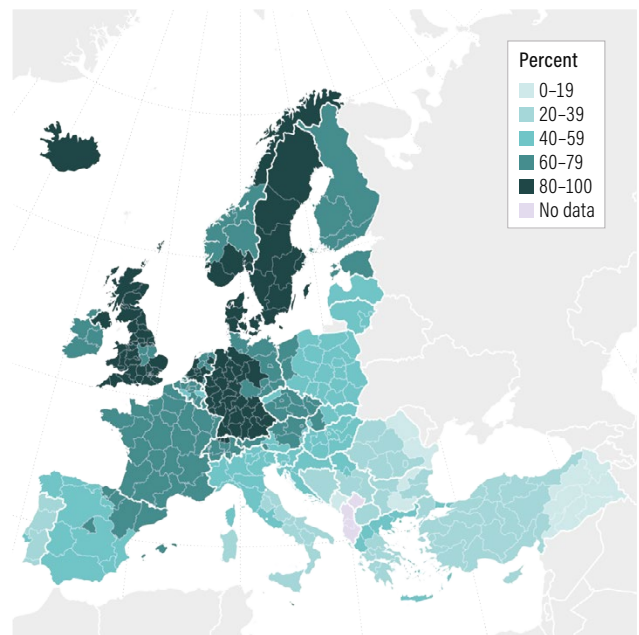
2. 2018



Percent of individuals aged 16-74 who ordered private goods or services online in the past year  
1. 2008



2. 2018



Source: Europe 4.0 team based on Eurostat.

# IMPLICATIONS FOR A EUROPEAN TECHNOLOGY MODEL THAT DELIVERS ON COMPETITIVENESS, MARKET INCLUSION AND CONVERGENCE

A European technology model has to deal both with the features of the new technologies and with the key features of Europe. Box 1.2 summarizes the approach that the EU has taken in supporting the digital technology agenda. As the EU considers an updated digital strategy, the evidence presented above highlights three debates about how best to respond to the current wave of change in ways that fulfill its triple objectives.

## **BOX 1.2** Existing EU policy frameworks and investments for digital convergence and inclusion

The European Union (EU) has numerous strategies, regulations and instruments that address the productivity and innovative performance disparities between and within member states. This report looks at the experience of recent years, as well as the potential implications of the latest announcements on the EU's digital strategy.

### **Completing the digital single market (DSM) remains an outstanding goal**

To date, the key EU strategy related to digital convergence is the DSM, which aims to create the right conditions and a level playing field for digital networks and innovative services to flourish across Europe. A deal of progress has been made; 28 of the 30 regulations proposed under the Juncker Presidency have been implemented. However, the DSM remains an aspiration in several important dimensions. The continued fragmentation in the single market itself matters for the digital single market, as reflected in many important regulations that are yet to be harmonized across countries and continuing restrictions on trade in services (see Chapter 6).

### **Taking the lead in protecting data privacy, data sharing and competition in the digital economy**

This is where the EU has been a leader, implementing the General Data Protection Regulations (GDPR) in May 2018, making explicit the rights of individuals and obligations of collectors and processors of personal data. It is also pursuing a wider set of investigations of potential abuse

of dominant positions within the digital economy and taking greater steps to ensure a level playing field and ensuring the contestability of digital markets (see Chapter 7). The von der Leyen Presidency is preparing new ways of strengthening the EU's human-centric approach and competition policy for the digital economy.

### **Investing in funds that support technology diffusion and regional catch-up**

The European Structural and Investment Funds (ESIF) are the primary financial tool that the EU uses to address regional disparities. (The Annex lists the major EU initiatives and which of the triple objectives they aim to support.) The introduction of ex-ante conditionalities appears to have shaped the prioritization of digital investments using the ESIF, with regions shifting from investments of relative strength to investments in covering infrastructure gaps or shoring up areas of weakness. Horizon 2020 resources are better leveraged by innovation hubs and centers of excellence, but it also allocates funds across regions to assist with technology diffusion. Smart Specialization funds then complement them, seeking to build on applied R&D and building links to market opportunities. These generally larger ticket investments and overarching policy issues are — and need to be — complemented by more local interventions. These interventions should assist lower-performing regions to develop an enabling environment that is conducive to adopting and deploying digital technologies, even within traditional sectors (see Chapter 8).

This report argues that the framing of policy debates around the technology agenda matters — whether the three objectives are seen as being in tension with each other and the task is to manage trade-offs between the objectives, or whether there are solutions that can build on synergies between them. Understanding the underlying constraints that cause European firms to under-perform reinforces the ability to do the latter. The framework and evidence of this report informs a number of policy debates about how to expand market inclusion and geographic convergence in ways that reinforce Europe's competitive position.

- **Does completing the transition toward the data economy need more markets or more champions?** The evidence presented already shows that the gaps in digital markets remain significant. To the extent that technologies build on each other, closing gaps in Industry 3.0 needs attention as part of the larger Industry 4.0 agenda. The implication is that countries that have not facilitated the adoption of information technology cannot realistically hope that their economies will benefit significantly from Industry 4.0 technologies. As such, European countries need to look at where the gaps are in the adoption of Industry 3.0 technologies — and the broader set of constraints as to why they persist — as part of their larger technology agenda. There is a continuing agenda

regarding completing the formal rules of the digital single market. But beyond that, additional factors are needed to provide the incentives and ability to be competitive using technologies where scale is often a defining feature of success. The agenda is not just about technology. The complementary factors needed to support its use, such as skills, infrastructure and broader regulatory environment, are critical determinants of the pace and pattern of technological improvement. The 2016 World Development Report Digital Dividends pointed to the importance of the ‘analog complements’ of digital technologies—the education and infrastructure required, the rules and regulations that facilitate or impede technical progress, and even the cultural attitudes to social change that inevitably accompanies new technologies. By scaling digital markets and expanding the transition to using them more widely, the ability for champions to emerge and thrive is then more viable and sustainable.

- **Can Europe’s regulatory choices themselves be a source of comparative advantage and influence the values and standards of new technologies globally?** Regulations on competition will shape how contestable data markets will be, the extent to which SMEs and entrants can access data and be innovative too, and what safeguards there are against the abuse of a dominant position in markets where network effects can benefit users. Decisions about new technologies will also have broader cultural impacts, particularly regarding how AI will be used. Given European values on data privacy, the more a ‘privacy-by-design’ approach can be a source of comparative advantage, the greater the influence of this value globally. Conversely, if non-European tech giants operate in ways that violate Europe’s values, Europe is likely to face greater trade-offs in terms of productivity gains that its firms can access. Much is at stake in shaping the regulatory framework for how data can be used.
- **Is leapfrogging possible or is more attention needed to diffuse technologies to allow for catch up?** Concerns about competitiveness may focus attention on the frontier, but support for more firms and locations to catch up will be critical for inclusion and convergence. The variation across and within countries in readiness to use digital technologies is striking. Diffusion is not happening quickly or automatically. If the frontier is moving more quickly, the need for attention to facilitate greater diffusion of technologies will be important in raising productivity more widely. And it will be an important part of building larger markets that reinforce the ability of leaders to grow. Smoothing the pace of diffusion will be key to expanding market inclusion and convergence.

Much of this agenda is about understanding how technology is changing the ex-ante opportunities of different types of firms and regions. But there are also concerns about ex-post inequalities. Technological change can usher in new efficiency gains and improve people’s quality of life, but it can also be disruptive—and even destructive. The costs of disruption can be uneven across individuals. Technological change replaces certain types of skills and tasks, and it can shift the share of earnings between workers and capital (Autor, 2015; Autor and Salomons, 2016). The skills and social protection dimensions of technological change were addressed in the previous World Bank flagship on Europe, *Growing United*, and so are not discussed in much detail in this report (see preface). However, it should be noted that Europe has very strong redistribution programs, including generous tax and transfer policies, and social protection programs. Europeans should be more willing to embrace technological change, knowing that they have greater safeguards against the downside risks (Box 1.3).

### **BOX 1.3** Protecting workers from losses of jobs and income is also needed as part of a broader package seeking inclusive outcomes

With any technological change, or any change for that matter, there will be winners and losers. This report focuses on firms and locations. Other recent work by the World Bank look at the impact of technological change on jobs and wages. *Toward a New Social Contract: Taking On Distributional Tensions in Europe and Central Asia* (2019) looked at some of the recent trends in job losses associated with a wide understanding of technological change. While the estimates on jobs losses from automation

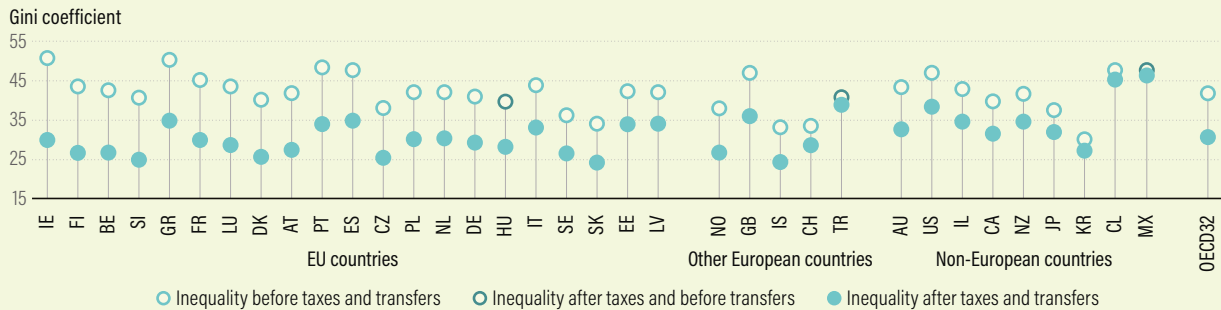
have come down from some of the alarming early rounds, the number of people affected is still sobering. That report, as well as *Growing United: Upgrading Europe’s Convergence Machine* (2018), discuss the redistribution mechanisms available in Europe to assist workers with transitions and the safety nets that can help those that may be displaced. This report notes that these coping policies are one of Europe’s strengths. They should provide additional assurances to embrace technological change.



The impact on workers is not only through jobs losses, earnings can also change. With declining shares of income going to labor in recent years, policies on how income should be distributed is part of the overall policy package. Many European countries have instituted tax and transfer mechanisms that are easily the most redistributive in the world (Causa and Hermansen, 2019). In 2016, for example, direct taxes, contributory benefits, and transfers reduced income inequality by 0.20 Gini points in the European Union, compared with less than half this magnitude in the

non-EU members of the OECD (Inchauste and Karver, 2017). While the Gini coefficient of market income is nearly 50 percent in the EU, governments reduce it to almost 30 percent for disposable income. The corresponding coefficients for non-EU members of the OECD such as Australia, Canada, Japan, South Korea, and the United States are 43 and 34 percent. Continental and northern EU member states affect the biggest redistribution, with Ireland, Finland, Belgium, Denmark, Austria, Luxembourg and France being especially effective in doing so (Figure B1.3.1).

**FIGURE B1.3.1** EU member states have the most redistributive tax and transfer arrangements (countries ordered from least to most redistributive, by country grouping)



Source: Causa and Hermansen (2019).

Note: EU = European Union; OECD = Organisation for Economic Co-operation and Development.

The European Union also provides incentives and instruments for its new member states such as the Czech Republic, Estonia, Hungary, Latvia, Poland, and Slovakia to institute similarly redistributive fiscal systems. Compared with countries at similar per capita income levels such as Chile, Mexico, South Korea and Turkey, they have much more redistributive public finance systems.

Source: Causa and Hermansen (2019).

Thus, many member states of the European Union are in fact relatively well prepared to mitigate the risks related the distributional consequences of technological change. The recognition of Europe's institutional advantages in dealing with risks should help allay the fears of Europeans and encourage them into being greater techno-optimists.

## A Call for More Action

Europe's relative lack of new global champions and continuing variation in the use of new technologies within and across countries makes it clear that more needs to be done to realize the potential that new technologies bring. If policy-makers do not respond to the increasing speed of change, or worse still see data-driven technologies mostly as a threat, then Europeans may miss their many economic benefits—but will still have to deal with their social and political complications. Change is happening even if new technologies are not accompanied by policies to prepare for them and to influence their effects. If the enabling policy environment is such that the response of firms or workers is timid or constrained, the opportunity to achieve all three objectives is diminished. Without realizing productivity enhancements, the gains in terms of competitiveness will be more limited, and there will be fewer opportunities to share across firms and locations.

Embracing technological change in ways that are consistent with all three goals, on the other hand, can help create greater overall demand, which is the impetus for the creation of new products and services, new tasks and new jobs. Europe is actively debating how best to engage and to shape its path forward (see Box 1.4). This report provides a framework and new evidence on how to guide these policy choices. Responses to the new opportunities and the risks that data-driven technologies imply for Europe will determine how well it meets its goals to expand its global share in technology while sharing the benefits widely within Europe. There is much at stake; it is time to rise to the challenge.

### BOX 1.4 How would the new EU data strategy of February 2020 address the digital dilemma?

The European Commission announced on February 19, 2020, a new and ambitious data strategy. This report provides new insights into how the new strategy will help Europe reach its ambitions. On the one hand, the new strategy focuses on strengthening Europe's competitiveness. It aims to leverage Europe's strength in operational technologies, while seeking to do more with the data generated by these technologies. The push to expand industrial Internet of Things (IoT) to inform a wider set of processes, the greater sharing of commercial data and wider use of public data, as well as the development of more B2B platforms within manufacturing, aims to harness elements of informational and transactional technologies to raise the competitiveness of Europe's operational technologies further. This is promising.

However, as the report makes clear, the EU's new data strategy is not likely to address growing tensions with the goals of market inclusion and geographic convergence unless complemented by additional investments and targeted policies. How the EU moves from strategic principles to regulations and investments will matter a great deal in the strategy's impact on the digital dilemma. The regulations on when and how data need to be shared will not only be about setting standards, but will be critical in determining whether smaller firms and entrants can realistically compete and adopt these new digital technologies. It is not just about the *de jure* rules, but about their impacts in practice. Here, three empirical insights are critical for Europe to succeed:

- First, while the earlier wave of informational technologies has been contributing to market inclusion, this might not continue to be true of the latest applications. In particular, the use of big data analytics and machine learning are widening performance gaps between larger and smaller firms, and between leading and catching-up regions. Thus, the new uses of digital technology being supported

by this strategy may reduce rather than enhance market inclusion and convergence in practice.

- Second, while B2C can enable a wide range of firms to use the platforms, the same has not yet been demonstrated for B2B; they are more successful for large value chains where there are economies of scale than for even medium-sized lead firms (Fraunhofer, 2019). So, while expanding transactional technologies could contribute to market inclusion and convergence, it might not necessarily be as true with B2B platforms.
- Third, to the extent there are digital skill and data management requirements and greater need for a conducive business environment to support the use of the underlying new technologies along these value chains, the evidence shows that smaller firms and firms in catching-up regions might need more active support to be able to absorb these technologies and seize the new opportunities. Access to digital opportunity may not be enough.

The new data strategy raises the stakes and the potential of how the data economy can elevate European competitiveness. The analysis presented here provides ways to help realize this potential while avoiding some of the trade-offs. To make this data strategy feasible, more still needs to be done to complete the digital single market to enable data to flow and be used in practice (see Chapter 6). To be inclusive of smaller firms and new entrants and to support regional convergence, both the rules (discussed in Chapter 7), and the efforts to support a wider deployment and adoption of these technologies (discussed in Chapter 8) will be needed. This augmented approach would then reinforce the potential to attain all three objectives—and strengthen the potential for Europe's approach to data as a source of comparative advantage.

Source: Europe's Digital Strategy, February 19, 2020, and Europe 4.0 team.

## Note

1. There is of course a selection issue, it may well be that more productive firms are the ones that adopt the technology so the results cannot be interpreted causally.

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## CHAPTER 2

# THE FRAMEWORK: UNDERSTANDING THE ECONOMIC EFFECTS OF DIGITAL TECHNOLOGIES

The first step is to understand how digital technologies are likely to change the competitive balance between Europe and the rest of the world, between smaller and larger enterprises, and between more and less advanced countries and regions in Europe. It is then possible to surmise whether new technologies will make it easier or harder to achieve Europe's triple objectives of economic competitiveness, market inclusion, and geographic convergence.

## NEW DIGITAL TECHNOLOGIES AND EUROPE 4.0

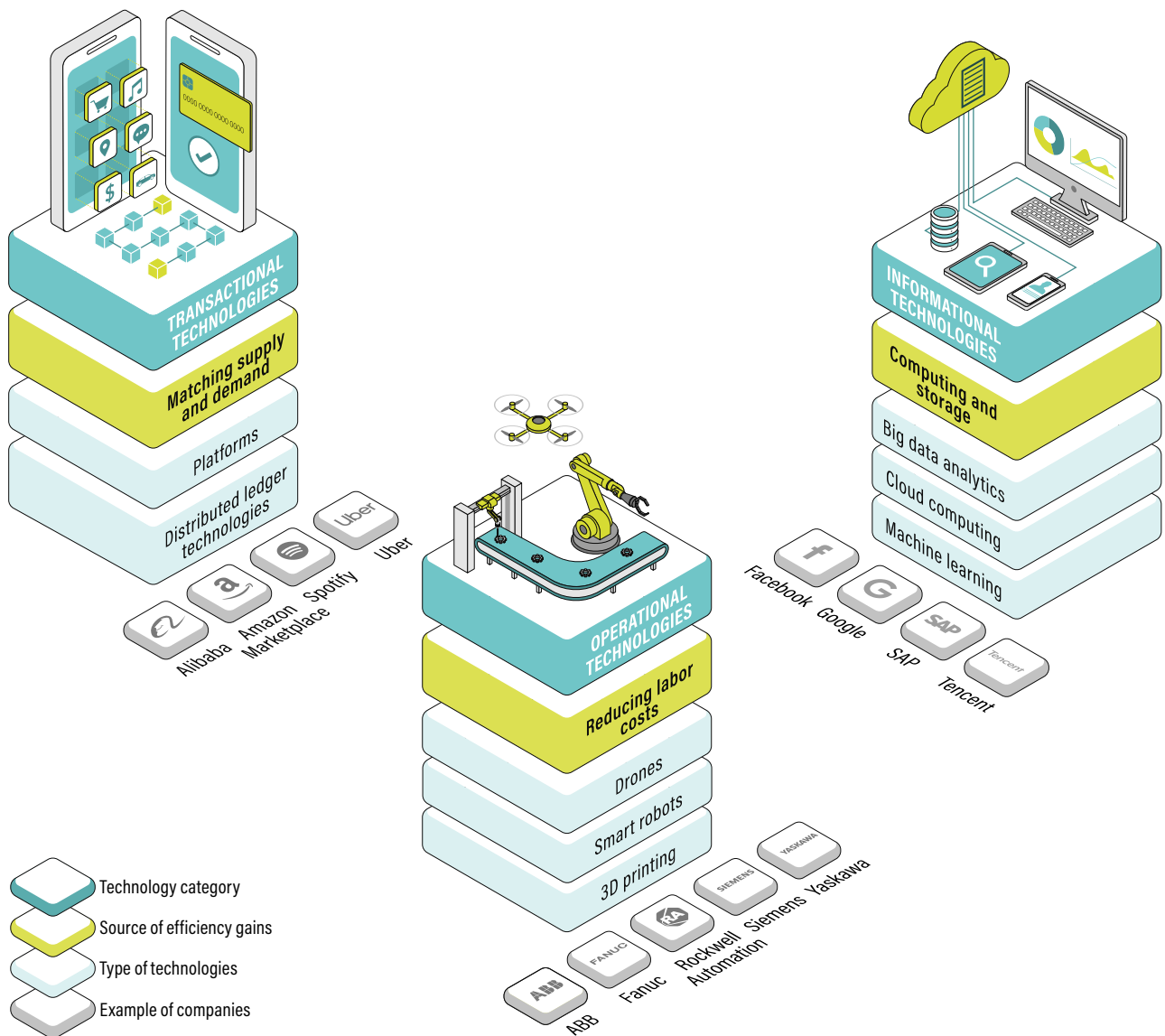
So far, the report has talked about 'digital Industry 4.0 technologies'. These are process technologies within Industry 4.0 that are driven by the use of data and can be applied to a range of sectors. But even this set of technologies is not monolithic. Taking into account the underlying problems that different digital technological solutions are trying to address means that they operate with different economic dynamics. The rest of the report takes these distinctions seriously. Indeed, a significant contribution of the report is precisely to be more precise about differential impacts of different types of technological change.

This report uses a functional classification of three different data-driven technologies and proposes a conceptual framework to identify their main effects on Europe's three objectives of competitiveness, market inclusion and geographic convergence. The aim is to understand whether and how different types of technologies may have different impacts across each of Europe's three goals. If some technologies only contribute to some objectives but introduce new challenges in addressing others, policy choices need to take this into account.

A closer look reveals that new digital technologies vary based on differences in their underlying source of efficiency gains. Using a classification that looks at the nature of cost savings, Europe 4.0 organizes these technologies into three types (Figure 2.1):

- **Transactional technologies that digitize business models.** Examples include digital ecommerce platforms and blockchain. The fundamental driver is the falling cost of matching demand and supply. The main effect is to reduce information asymmetries and facilitate market transactions that might otherwise not happen.
- **Informational technologies that exploit the exponential growth of data.** Examples include business management software, cloud computing, big data analytics, and machine learning. The fundamental driver is the falling cost of computing. The main effect is to lower coordination costs.
- **Operational technologies that combine data with automation.** Examples include ‘smart’ robots, 3D printing, and the Internet of Things (IoT). The fundamental driver is the falling cost of automating routine functions with ‘smart’ machines. The main effect is to reduce production costs including labor, materials and, in many cases, energy.

**FIGURE 2.1** The three types of data-driven technologies have different economic drivers



Source: Europe 4.0 team.

# A SIMPLE FRAMEWORK FOR EUROPE: BRINGING TOGETHER THREE TECHNOLOGIES AND THREE OBJECTIVES




With different sources of efficiency gains, a critical question is whether transactional, informational, and operational technologies have different economic dynamics. For example, will any of them lead to greater concentration of production in some locations, or in larger enterprises that use more capital-intensive forms of production? Whether they do or not matters significantly for Europe’s triple objectives of economic competitiveness, market inclusion, and geographic convergence. Figure 2.1 summarizes the working hypotheses regarding the potential impact of these three data-driven technologies on Europe’s triple objectives.

Economic competitiveness is measured by productivity, trade and investment patterns, while market inclusion reflects the gap between large and small firms and between labor and capital, and geographic convergence reflects differences in production outcomes and technology diffusion between European countries and regions at the NUTS2 level. There will be also be reference to country groupings as defined in Golden Growth (Gill and Raiser, 2012).<sup>1</sup> This includes the European Union (EU)-14 (those in the EU prior to the accession of 10 candidate countries in 2004, now minus the UK so EU14 rather than the EU15 in the 2012 publication), the EU-13 (those countries that acceded to the EU between 2004 and 2013), and EU candidate countries.

## WHAT WE CAN EXPECT

All three types of digital technologies will contribute to economic competitiveness by raising efficiency. The trade-offs might appear in what these technologies imply for market inclusion and geographic convergence (Figure 2.2).

**FIGURE 2.2** Expected impact of three types of technologies on Europe’s three policy objectives for users of technology

	 <b>Transactional technologies (platforms)</b>	 <b>Informational technologies (big data analytics)</b>	 <b>Operational technologies (smart robotics)</b>
<b>Competitiveness</b>	+	+	+
<b>Inclusion</b>	+	+	-
<b>Convergence</b>	+	-	-

Source: Europe 4.0 team.

For market inclusion, the key dimension is how scale itself matters—how much investment is needed by a firm to participate and whether there are threshold effects that make it worthwhile to deploy a technology. If there are large upfront investments or the need to have larger operations over which to spread the costs of the technology upgrading, fewer small firms will see it as worthwhile to adopt the new technology.

For convergence, the greater use of digital processes within businesses should make geography matter less. Being part of a virtual network should make it easier for firms in remote regions to connect to economic opportunities. However, supporting factors external to the firm remain crucial to actual technology adoption and therefore where firms choose to locate. For example, if high-speed broadband and advanced skills are important pre-requisites, businesses will likely locate in places where these are more easily available.

Transactional technologies such as digital platforms make markets more efficient by better matching supply and demand. For small firms and self-employed workers, this should be especially beneficial, letting them access a wider market than they could do on their own. Scale itself is not necessary for firms to benefit from using these matching platforms. To the extent that services can be provided digitally, geography should also matter less. Transactional platforms enable firms in less developed regions to benefit from their distribution and logistics networks, and therefore their ability to reach a wider set of potential customers. The IT infrastructure and skills needed to use these platforms are also not that high. In sum, the working hypothesis is that transactional technologies are likely to raise competitiveness, and not lead to greater concentration of production, either in leading regions and countries or in larger firms.

The entire range of informational technologies—from business management software and cloud computing to big data analytics and machines learning—will aid the competitiveness of users. Scale per se is not important for many informational technologies. For example, cloud computing reduces upfront capital expenditures associated with hardware, while software platforms reduce the need for investing in a critical mass of skilled workers. These informational technologies also provide inexpensive coordination channels to facilitate greater fragmentation of production, thereby contributing to convergence. However, this potential for market inclusion and convergence might weaken with AI-enabled informational technologies such as machine learning. SMEs will not have the scale to generate big data. The use of machine learning algorithms and big data analytics might also have demanding needs in terms of the supporting infrastructure for firms to be able to use them, particularly in terms of access to high-speed broadband and advanced skills. In sum, the working hypothesis is that the diffusion of informational technologies is likely to help meet all three of Europe's objectives, although there might be increasing trade-offs more recently between competitiveness, on the one hand, and market inclusion and convergence, on the other, with the spread of AI.

Operational technologies such as robots, 3D printing and the IoT are likely to raise the productivity of users by substituting workers with 'smarter' more efficient machines. At the same time, they entail high fixed cost investments that are most effective when working at scale, making their adoption more likely among larger firms. They also could facilitate more activities being done in a single location, with additional or 'smarter' robots added to the line, rather than serving as a force for decentralization. Adopting data-driven operational technologies involves changing and reoptimizing the production process itself. Given the expenses and the need to undertake significant reorganizations of plants and potentially supply chains, it is likely for new 'data' equipment to be installed in existing production facilities to improve the efficiency of existing processes. The higher skill needs associated with them also reinforce the advantage of existing facilities located nearer to R&D centers of excellence. In sum, the working hypothesis is that the diffusion of operational technologies is likely to boost competitiveness, yet lead to the greater concentration of production in larger firms that use more capital-intensive forms of production and in leading regions or countries.

# WHAT WE FIND

Based on a rich evidence-base, we find that transactional, informational, and operational technologies differ in their contributions to Europe's triple imperative. New digital technologies create new tensions across Europe's three objectives of being competitive, ensuring inclusive access to market opportunities, and fostering convergence across regions. The occurrence of such trade-offs depends on the underlying characteristics of the technologies, as well as the necessary complementary factors such as the quality of infrastructure, skills and governance. The evidence shows that transactional technologies do help connect firms to larger markets at very low cost and, as such, can help smaller firms and firms in more remote locations to be more productive. The evidence also confirms that informational technologies such as enterprise resource planning (ERP) software or cloud computing provide efficient services at a low cost that can help smaller firms. However, while in theory they should help more remote locations, the quality of supporting infrastructure and skills to use them are not always available in more lagging regions. Operational technologies, such as autonomous robots, require higher upfront investments and rely on more scale economies and thus favor larger firms. The greater use of 'smart' automation is also serving to concentrate more production in existing hubs. Thus, as shown in Box 2.1, the technologies vary in how they contribute to Europe's three objectives.

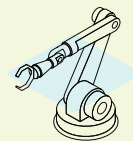
## BOX 2.1 Europe faces a Digital Dilemma between its objectives and its performance



**Transactional technologies**



**Informational technologies**



**Operational technologies**

### a. Digital technologies vary in their contributions to Europe's Triple Objective

	Transactional technologies	Informational technologies	Operational technologies
<b>Competitiveness</b>	+	+	+
<b>Market inclusion</b>	+	+	-
<b>Geographic convergence</b>	+	-	-

### b. Europe's performance across technologies also varies

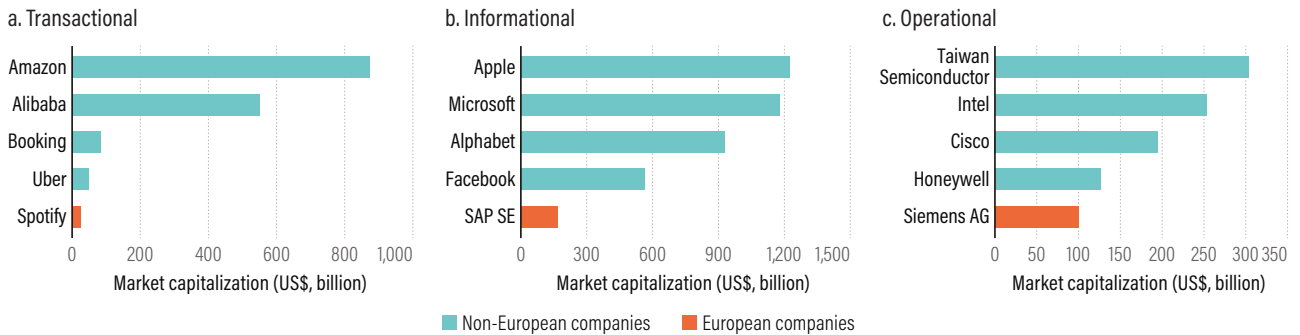
	Transactional technologies	Informational technologies	Operational technologies
<b>Creation</b>	-	-	+
<b>Adoption</b>	-	-	+

Source: Europe 4.0 team.

Together, Europe faces a digital dilemma: where impact on inclusion and convergence is strongest, Europe's performance is modest; and where performance is strongest, the impact on inclusion and convergence is weaker.

Europe's performance also varies across technologies, in terms of having frontier companies and in the rate of firm adoption. The evidence shows that Europe has few leading global firms in either transactional (Spotify) or informational technologies (SAP), and rates of adoption are fairly low. In contrast, Europe has many leading firms in operational technologies and rates of adoption are also fairly high (Figure 2.3).

**FIGURE 2.3** Europe has lost out in the first wave of digital transformation



Source: Europe 4.0 team calculations, using data from Bloomberg.

This evidence reflects a digital dilemma in Europe. Operational technologies are where European firms are most competitive, but these tend to concentrate opportunities in larger firms, and existing production and knowledge hubs. Transactional technologies have the maximum potential to promote market inclusion and geographic convergence, but this potential is only partially being realized and few European transactional digital platforms are globally competitive. Informational technologies fall in between: with some market inclusion, but little spatial convergence. And over time, the newest informational technologies have a pattern more like the operational technologies with benefits being realized by larger firms in leading regions. Here too, technology adoption is not widespread and Europe has few companies that are global leaders. The imbalance between objectives and performance needs to be addressed.

The contribution of this report is thus threefold. First, it provides a framework for distinguishing why groups of digital technologies have differential contributions to Europe’s three goals. Second, it provides empirical evidence substantiating Europe’s performance in using and creating the three types of digital technologies — and their contributions or lack thereof to inclusion and geographic convergence. Third, it provides policy recommendations to address the digital dilemma facing Europe, providing a way forward to realize the full potential of Europe 4.0.

## Note

1. This report builds on two earlier reports looking at drivers of convergence and the role of technology in Europe, *Golden Growth* (2012) and *Growing United* (2018), and extends the World Development Report 2015 on Digital Dividends to examine in greater detail the contributions across types of digital technologies and across the three goals of competitiveness, inclusion and convergence.

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## CONCLUSION TO PART I

The framework structures the rest of the report. Based on the underlying economic dynamics, it is important to distinguish between different types of technologies. They vary in their potential contributions to Europe's three goals. Part I has provided the broader context for this current wave of technological change, how and why digital technologies vary. It has laid out the hypotheses on how each technology is likely to contribute to Europe's triple objectives of competitiveness, market inclusion and geographic convergence.

Part II takes each of the three technologies in turn and tests empirically how their adoption is impacting each of these three objectives. Part III, the policy section, then looks at how the digital dilemma is playing out in each of the three technologies, and what priority investments and reforms are needed to help resolve it. Part III discusses how to strengthen performance where the potential contributions to the triple objectives are not being realized, or what supplementary initiatives are needed to expand the set of firms that can access the new technologies.

The aim of the framework is to highlight why, whether and how different technologies may make it easier or harder for Europe to meet its three objectives. And then to look at the policy mix that addresses where the objectives may be diverging. The aim is to help Europe achieve Europe 4.0, where it can embrace new technologies so as both to expand its role globally and meet its goals to share the benefits domestically through fostering greater market inclusion and geographic convergence.

The central question tackled in this report is whether the new round of data-driven technological change — summarized as data-driven Industry 4.0 — will change Europe for the better or for the worse. That is, are these new technologies a threat to European competitiveness, inclusion and convergence, or do they present — with the appropriate supporting structures, policies and programs — an opportunity to simultaneously expand its share in the global economy and distribute the benefits widely within Europe?

The answer to this question is yes; Parts II and III of this report show why Europeans should be both worried and optimistic. The digital dilemma is real, but there are clear ways forward to address it.



# PART II

CHAPTER 3:  
**Transactional Technologies**

CHAPTER 4:  
**Informational Technologies**

CHAPTER 5:  
**Operational Technologies**

## INTRODUCTION TO PART II

Part II provides the empirical foundation of the report. We analyze each segment of the 3x3 framework and organize the next three chapters according to our new economic categorization of digital technologies associated with Industry 4.0 — transactional, informational, and operational. The three chapters in this section first describe Europe’s performance with regard to both the use and creation of these digital technologies. They subsequently provide evidence of how each technology category relates to Europe’s triple objectives of competitiveness, market inclusion and convergence:

- Chapter 3 on transactional technologies focuses on digital platforms and distributed ledger technologies such as blockchain. Digital platforms, in turn, are restricted to those that enable third-party transactions. These include ecommerce marketplaces and sharing economy platforms, but exclude innovation platforms that may also facilitate market exchange. This choice reflects their relevance for fundamentally reducing transaction costs but also constraints on data availability.
- Chapter 4 on informational technologies focuses on enterprise resource planning (ERP) and customer relationship management (CRM) software, cloud computing, big data analytics, and machine learning. This choice reflects their relevance for fundamentally reducing the cost of computing but also constraints on data availability.
- Chapter 5 on operational technologies focuses on industrial robots, the Internet of Things (IoT), and 3D printing as the relevant technology set. This choice reflects their relevance in reducing the importance of labor costs among routine functions in the production process but also constraints on data availability.

For competitiveness, the focus is on productivity, international trade and investment patterns, while there is some discussion on the prevalence of market players at the technological frontier. For market inclusion, the focus is on the gap between large and small firms, as well as on implications for the demand for labor. For geographic convergence, the focus is on differences in production outcomes and the technology itself between European countries and regions at the Nomenclature of Territorial Units for Statistics (NUTS) 2 level. There is also reference to country groupings as defined in *Golden Growth* (Gill and Raiser, 2012). This includes the EU-14 (those countries in the EU prior to the accession of 10 candidate countries in 2004),<sup>1</sup> the EU-13 (those countries that acceded to the EU between 2004 and 2013),<sup>2</sup> and EU candidate countries.<sup>3</sup>

The three following chapters are informed by a wealth of new data that the World Bank Group has compiled for the first time. The data used draw on Eurostat’s country-sector-firm size adoption rates of different technologies, as well as measures of productivity. In addition, there is detailed country-sector-year data on the use of industrial robots from the International Federation of Robotics that allow for a broader discussion of convergence not only within Europe, but also on whether there is evidence of reshoring back to Europe from other regions when combined with data on greenfield FDI announcements from the fDi Markets Database.

Furthermore, a partnership with the European Investment Bank (EIB) enabled us to analyze data at the firm level based on EIB's new survey of firms and their adoption of digital technologies. While only available for one year, it is the most up-to-date source of data on technology adoption at the firm level in Europe and also provides an opportunity to bring in comparisons with the United States.

## Notes

1. This was the EU-15 prior to the United Kingdom exiting. The remaining 14 are Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Denmark, Ireland, Greece, Spain, Portugal, Austria, Finland and Sweden.
2. Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria and Romania.
3. Albania, North Macedonia, Iceland, Montenegro, Serbia, Turkey, Bosnia and Herzegovina, and Kosovo.



## CHAPTER 3

# TRANSACTIONAL TECHNOLOGIES

## INTRODUCTION

The spread of the internet has facilitated market transactions by reducing search costs. It is easier to find and compare information about potential economic transactions online than offline. As a result, lower search costs associated with the internet are likely to increase the quality of matches between buyers and sellers, as well as between firms and workers. Kuhn and Mansour (2014) find that individuals who used the internet in their job search were more likely to match to an employer. Dana and Orlov (2014) show that airlines are better able to fill flights to capacity by selling tickets online. Similarly, Ellison et al. (2014) show that online buyers are better able to find the specific books they want. New markets are also created. Anenberg and Kung (2015), for example, show that online search enabled the rise of a market for truck-based mobile restaurants ('food trucks').

Digital markets have given rise to online platforms, which provide a structure that can take greater advantage of low search costs to create efficient matches (Jullien, 2012). These platforms are marketplaces that typically serve as intermediaries between buyers and sellers to facilitate market exchange (Nocke, Peitz and Stahl, 2007; Goldfarb and Tucker, 2019). Most platform ecosystems comprise a platform owner (or central firm), suppliers (or complementors) and end users (Evans and Gawer, 2016).<sup>1</sup> The fundamental driver is that these online platforms more effectively match demand and supply by reducing information asymmetries between consumers and producers. As a result of the exchange, data collected and transmitted over these platforms reveal patterns that further facilitate the matching process (OECD, 2019).

Digital platforms, such as eBay, Etsy and Taobao, first emerged in retail commerce to connect buyers and sellers of products.<sup>2</sup> The variety of such online markets is increasing more than ever before across a range of sectors matching workers and firms, investors and entrepreneurs, vacant rooms, and travelers, and so on. Several of these markets are referred to as the 'sharing economy' because people can use unused objects or skills more efficiently (Horton and Zeckhauser, 2016). Examples include transportation services (e.g., Uber, Lyft, Blablacar, Didi Kuaidi), accommodation (Airbnb, Kozaza, Couchsurfing), household services (TaskRabbit, Care.com), and computer programming (oDesk, Freelancer). Airbnb, for instance, is set up as a decentralized marketplace, while Uber internalizes the matching process (Credit Suisse, 2015).

Blockchain and other distributed ledger technology (BDLT) also holds the potential to radically reduce transaction costs. Distributed ledger technology (DLT) is a distributed database where data can be recorded and shared across the nodes of a network. Blockchain is a type of DLT where information is consolidated into ‘blocks’ linked in an ‘append-only’ fashion, adding close-to-immutable<sup>3</sup> information layers to the ledger. Therefore, BDLT records transactions between two parties efficiently, and in a verifiable and permanent way. It thereby also enables smart contracts, which are software programs embedded in a distributed ledger and triggered by specific data patterns that can enforce rules and functions across the ledger (Dorfleitner et al., 2017). The result is greater peer-to-peer trust, which reduces transaction costs. BDLT can be applied across different sectors, but its potential is best illustrated by current applications in the financial sector (World Bank, 2017; Casey et al., 2018). Recent estimates foresee blockchain spending in Europe led by the financial sector reaching US\$1.8 billion by 2021.<sup>4</sup>

Transactional technologies, by definition, reduce transaction costs and are therefore likely to strengthen globally fragmented production. Online marketplaces reduce search costs between buyers and suppliers, which are likely to be even higher when the potential trade opportunity is cross-border. Similarly, BDLT can facilitate cross-border payments and remittances through smart contracts that reduce the need for financial intermediaries. Furthermore, BDLT could allow for recording the actions of firms in a transparent, streamlined fashion, and in line with trading and settlement-related regulatory requirements that vary from country to country. Transactional platforms generate new jobs in the gig economy, at times displacing incumbents but also creating new markets. Ride-sharing platforms, for instance, may reduce the number of incumbent taxi drivers, while creating a larger pool of individuals who participate as service providers on the platform, with the aggregate impact being an empirical question. Platforms that match service providers with potential customers may create more jobs through enabling hitherto unrealized transactions. What these platforms do, without doubt, is create a new set of freelancers in an expanding gig economy.

Online platforms can expand access to markets for smaller firms because they provide the necessary logistics and distribution networks. Blockchain too through smart contracts can improve access to finance, which is especially problematic for new and smaller firms without the requisite credit histories and collateral. At the same time, network effects, which call for a broad user base to attract developers, sellers or other potential participants, can help companies scale rapidly and lead to ‘winner-takes-all’ markets in the provision of the platform itself. This might increase the gap between them and the wider distribution of firms. Companies with the highest market capitalization in the world are largely platform businesses, including those that enable market transactions, and many appear in the Fortune 500 list (OECD, 2019).

Transactional technologies may lead to greater dispersion of economic activity to the extent that they provide enabling infrastructure and increase the prospects of remote delivery. Ecommerce platforms can increase market entry for firms not based in major urban centers through their logistics infrastructure and distribution networks. Similarly, blockchain can improve access to finance in regions with less developed financial systems because it substitutes for financial intermediaries. Furthermore, the matching process facilitated by online platforms can facilitate the remote delivery of a range of professional services. This could expand opportunities for firms or service providers in less populated areas to expand their access to markets.

This chapter sheds light on whether and how transactional technologies are (re)shaping competitiveness, market inclusion, and geographic convergence in Europe. The analysis that follows focuses on digital platforms and blockchain as the relevant technology set. Digital platforms, in turn, are restricted to those that enable third-party transactions. These include ecommerce marketplaces and sharing economy platforms, but exclude primarily innovation platforms that may also facilitate market exchange, e.g., Apple, Google, Facebook. This choice reflects their relevance for fundamentally reducing transaction costs, as well as constraints on data availability. Competitiveness is measured by productivity, trade and investment patterns. Market inclusion reflects the gap between large and small firms, and between labor and capital. Geographic convergence reflects differences in production outcomes, as well as technology diffusion and creation between European countries and regions at the NUTS2 level.

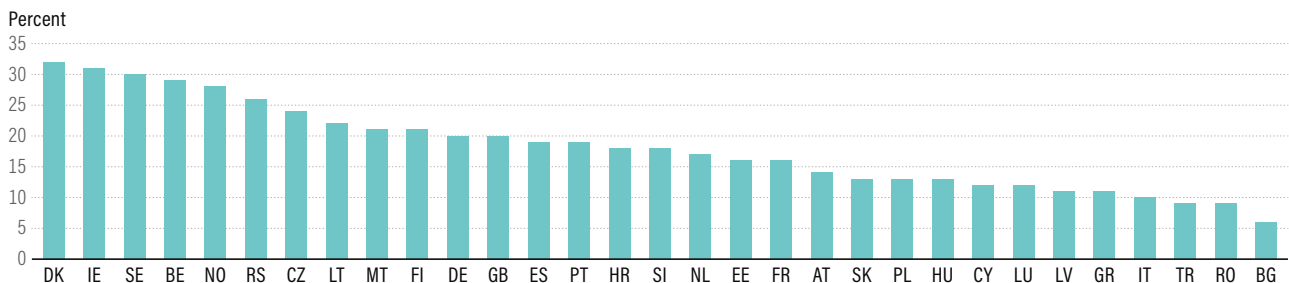
# THE TECHNOLOGY LANDSCAPE IN EUROPE

## How widespread is the use of transactional technologies in Europe?

The share of firms that meet even a minimum threshold of selling online in Europe is far from universal. Member countries of the EU-14 North and Central groups as well as Norway feature prominently among countries with the highest share of firms selling at least 1 percent of their turnover online in Europe in 2018. This includes Denmark (32 percent), Ireland (31 percent), Sweden (30 percent), Belgium (29 percent) and Norway (28 percent). At the same time, Serbia (26 percent), the Czech Republic (24 percent) and Lithuania (24 percent) had the next highest share of firms selling online—all outside the EU-14—and ranked higher than Finland (21 percent), Germany (20 percent) and the United Kingdom (20 percent) (Figure 3.1).

**FIGURE 3.1** The share of firms that meet even a minimum threshold of selling online in Europe is far from universal, with both EU-14 countries and others constituting the top 10

Share of firms that sold at least 1 percent of their turnover online, 2018



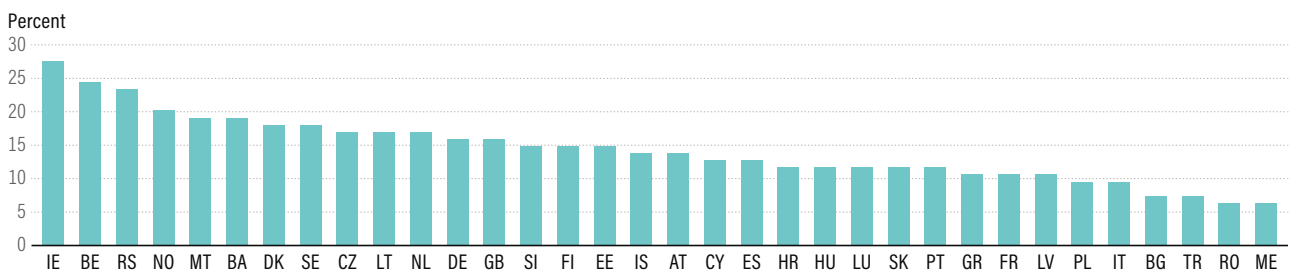
Source: Eurostat.

Note: EU = European Union.

The use of a B2C website or app to sell online in Europe is also far from universal. Member countries of the EU-14 North and Central groups and Norway again feature prominently among countries with the highest share of firms that used a B2C app or website to sell online in Europe in 2018. These include Ireland (26 percent), Belgium (23 percent), Norway (19 percent), Denmark (17 percent), Sweden (17 percent), the Netherlands (16 percent), and Germany (15 percent). Yet, as many as four countries outside the EU-14 are included in the top 10 here too—Serbia (22 percent), Bosnia and Herzegovina (18 percent), the Czech Republic and Lithuania (both 16 percent) (Figure 3.2). The diffusion of B2C platform technologies among firms in the EU-27 is roughly on a par with the United States (EIB, 2019).<sup>5</sup>

**FIGURE 3.2** The share of firms that use a B2C website or app to sell online in Europe is also far from universal, with both EU-14 countries and others constituting the top 10

Share of enterprises that used a B2C app or website to sell online, 2018



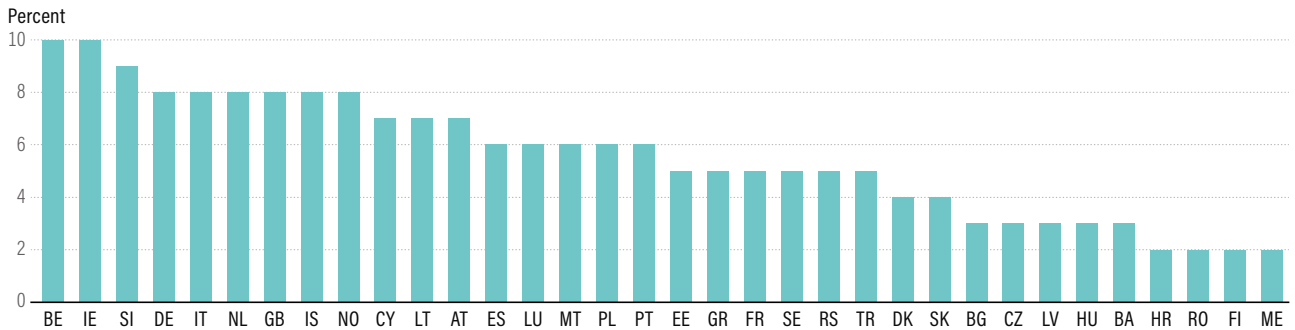
Source: Eurostat and OECD.

Note: B2C = business-to-consumer; EU = European Union.



The share of firms that use an ecommerce marketplace to sell online is lower still, but higher among countries in the EU-14 group. The penetration rates vary between 2 and 10 percent, with countries belonging to the EU-14 North and Central groups comprising all but two of the top 10. These include Belgium and Ireland (both 10 percent), as well as Germany, Norway, Iceland, the Netherlands and Italy (all 8 percent). Outside Norway, the United Kingdom and the EU-14, Slovenia has the highest share at 9 percent (Figure 3.3). The Enterprise Europe Network (2018) similarly estimates a much smaller ecommerce market in East Europe (€24.5 billion) compared with West Europe (€252.9 billion), with the former also having grown less quickly than the latter (9.1 percent compared with 12.9 percent) during 2014/15.<sup>6</sup>

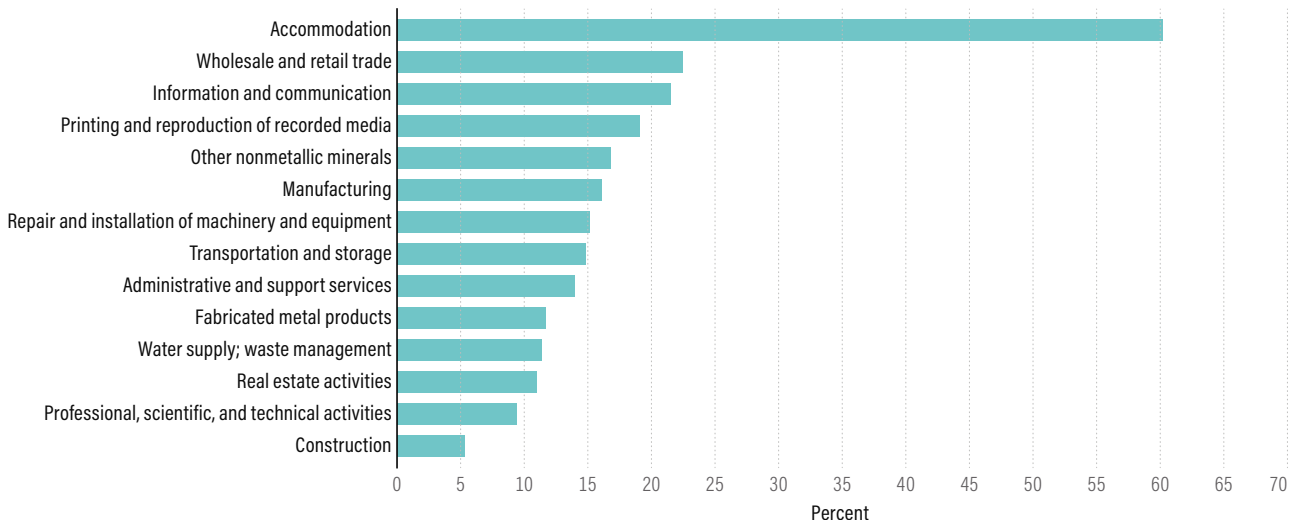
**FIGURE 3.3** The share of firms that use an ecommerce marketplace to sell online is even lower, but higher among EU-14 countries  
Share of firms that sold their goods through an ecommerce marketplace, 2018



Source: Eurostat.  
Note: EU = European Union.

The use of digital platforms that enable market transactions in Europe is most prevalent in a subset of the services sector. The share of firms selling at least 1 percent of their turnover online in Europe, at 60 percent, is the highest in accommodation services. Other services subsectors, such as wholesale and retail trade, and information and communication services are also intensive in the use of transactional platforms (Figure 3.4). Ecommerce is more prevalent among firms in the services sector, on average, than in the manufacturing sector (UNCTAD, 2015).

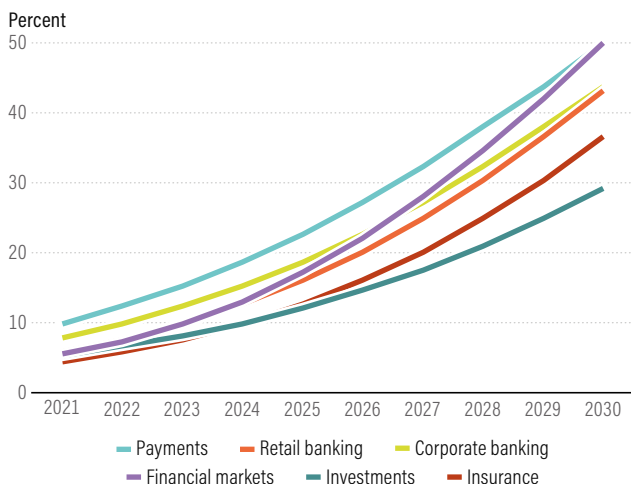
**FIGURE 3.4** Digital sales in Europe are most prevalent in accommodation, trade, and information and communication services  
Share of enterprises with at least 1 percent turnover sold online, by sector, 2018



Source: Eurostat.

**FIGURE 3.5** The market penetration of BDLTs in Europe's financial sector is expected to increase substantially over the next decade

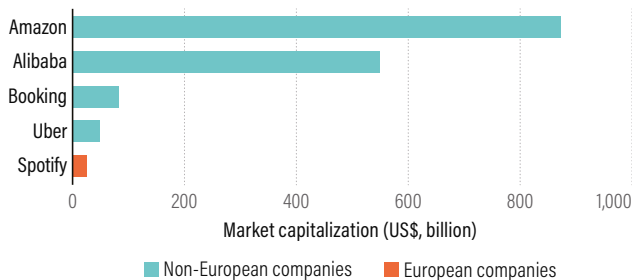
BDLT penetration rates in Europe's financial sector, by segment, 2021–30



Source: Padilla et al. 2019

Note: BDLT = blockchain and distributed ledger technology.

**FIGURE 3.6** Europe lags in market capitalization of leading transactional platforms, 2019



Source: Authors' calculations

countries that are in the top 20 include Finland, Germany, Italy, Spain and the United Kingdom (Szczepański, 2018). While there is some evidence that the bulk of app developer revenue goes to those that have an international presence (e.g., Finland's Supercell), many European app developers remain domestic (Szczepański, 2018).<sup>9</sup>

Firms in Europe are among those pioneering the application of BDLT initiatives worldwide. The largest global banks are at the forefront of BDLT projects, including European players such as BNP Paribas, Crédit Agricole, and ING. For example, Komgo—started in September 2016 as a mutual initiative of ING, Société Générale and Mercuria in Geneva, Switzerland—offers blockchain-based assets such as on-chain timestamped and immutable data, which provide peer-to-peer exchange of documents necessary for financial transactions in commodity value chains. While most BDLT start-ups are in the United States, there are some in Europe too. Founded and first incorporated in Berlin in 2014, SatoshiPay is a private distributed machine-to-machine payment system through which users can be charged micro-amounts<sup>10</sup> to access digital content (Consilium, 2017). This addresses the high transaction costs associated with Know-Your-Customer (KYC) processes in usual payment systems. Founded in 2016 in Leuven, Belgium, SettleMint provides a toolkit to accelerate the diffusion of blockchain-based apps that reduce the cost of financial intermediation.

The use of BDLTs is currently negligible globally, including in the financial sector, but market penetration in Europe is expected to increase substantially over the next decade. Estimates suggest that the speed of diffusion in the implementation of BDLT will vary across different segments of the European financial market—payments, retail banking, corporate banking, financial markets, investments, and insurance. The market share of BDLT-based products and services is estimated to reach 10 and 50 percent in each of these segments by, respectively, 2024 and 2034 at the latest. The diffusion period for payments is expected to be the fastest, with BDLT penetrating 10 percent of the market segment by 2021 and 50 percent by 2030 (Figure 3.5). This increase in BDLT market penetration is also expected to expand each of these financial sector segments, ranging from a cumulative market growth of 12.6 percent for investments to 36.1 percent for financial markets between 2019 and 2030 (Padilla et al. 2019).<sup>7</sup>

## Is Europe a global leader in the creation of transactional technologies?

Evidence suggests that Europe lags both North America and Asia in the prevalence of digital platform enterprises. Evans and Gawer (2016) identified 82 platform enterprises in Asia, 64 in North America, 27 in Europe, and three in Africa and Latin America.<sup>8</sup> They further note that, of the US\$ 4.3 trillion value of digital platforms globally, nearly three-quarters are accounted for by those in North America, 20 percent by those in Asia, and less than 5 percent by those in Europe. Among the leading digital platforms that enable market exchange, only Spotify is European (Figure 3.6).

Other evidence indicates that China and the United States have the most app developers globally. However, it is worth noting that revenues of the top app companies in Europe are sizable (estimated at US\$63 billion) and growing. European

# TRANSACTIONAL TECHNOLOGIES AND EUROPE'S ECONOMIC COMPETITIVENESS

## Is the use of transactional technologies associated with higher levels of productivity in Europe?

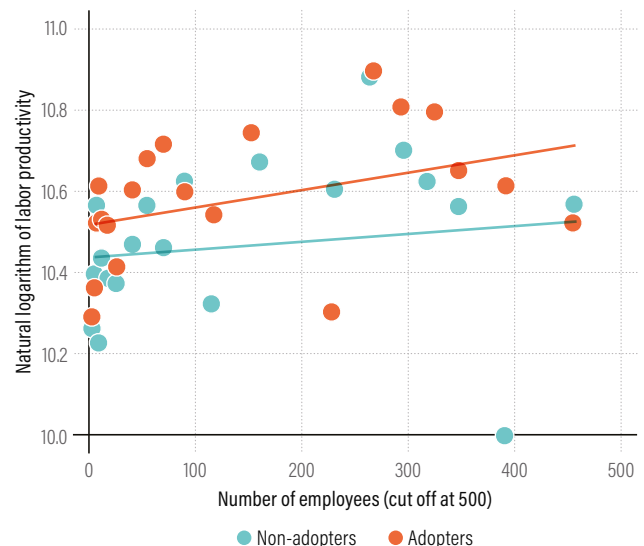
Based on firm-level data from 14 European countries—Austria, Denmark, Finland, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Slovenia, Sweden and the United Kingdom—UNCTAD (2015) finds that an increase in e-sales was positively and significantly related to growth in labor productivity from 2002 to 2010. Similarly, based on firm-level data from 10 OECD countries (Belgium, France, Germany, Hungary, Italy, Poland, Spain, Sweden, the United Kingdom and the United States) across four industries—hotels, restaurants, taxis, and retail trade—Bailin et al. (2019) find that the average service provider saw bigger multifactor productivity increases in countries with high online platform development<sup>11</sup> vis-à-vis the average service provider in countries with low online platform development between 2011 and 2017.<sup>12</sup> Recent EIB survey data from the EU-28 and the United States indicate that the partial or full implementation of (B2C and C2C) digital platforms is positively related to firm-level labor productivity across the entire distribution of firms (Annex 3, Table A3.1).<sup>13</sup> For a given firm size category, technology adopters are more productive than non-adopters (Figure 3.7).

These productivity gains are also reflected in lower prices for products sold online. Low search costs make it easier for consumers to compare prices, putting downward pressure on prices for similar products. Brynjolfsson and Smith (2000) compare prices of books and CDs at four internet-only retailers, four offline retailers, and four 'hybrid' retailers that had both online and offline stores. They show that online prices for these items were substantially lower than offline prices.<sup>14</sup> Relatively low online prices have been shown in a variety of other settings, including insurance (Brown and Goolsbee, 2002), automotive products (Scott Morton, Zettelmeyer and Silva-Risso, 2001), and airlines (Orlov, 2011). However, while prices may be lower, substantial price dispersion remains (Goldfarb and Tucker, 2019).

These positive productivity spillovers of transactional platforms have been enabled by data-driven decision-making. Take the example of ride-sharing platforms, such as Uber, where demand allocation mechanisms reduce information asymmetries by allowing drivers to observe which customers have the most attractive pick-up and drop-off locations (Wu, Wang and Zhu, 2016). Online platforms also have the option of licensing the data that they collect to third-party users to help them become more efficient. 'Aggregator' platforms that connect consumers to service providers in the market are a case in point. For example, Booking.com helped its clients realize an average of 7 percent more revenue by helping them identify consumers whose data indicate they would be willing to pay more (Li et al., 2019).

Most transactional platform companies themselves are more efficient than leading firms in traditional industries, albeit less efficient than innovation platform companies. Revenue per employee in the big innovation platform firms, including Apple, Facebook, Google, Microsoft, and SAP, are notably higher than those of

**FIGURE 3.7** For a given firm size category, firms that adopted B2C platform technologies are more productive than firms did not  
Labor productivity by firm size (number of employees) and adoption of B2C platforms, 2019

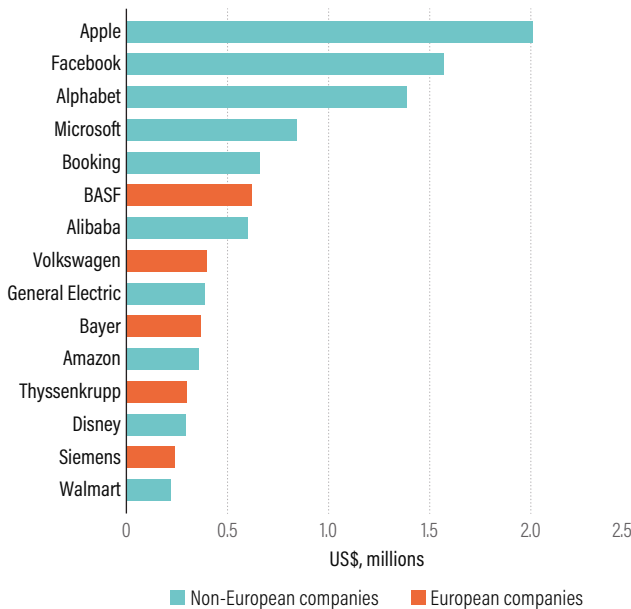


Source: EIB-WBG background paper by Cathles, Nayyar and Rückert (2020).

Note: Firms are weighted with value added. This bins scatter plot groups the number of employees into equal-sized bins (default = 20), and then computes the means for firm size and log labor productivity within each bin.

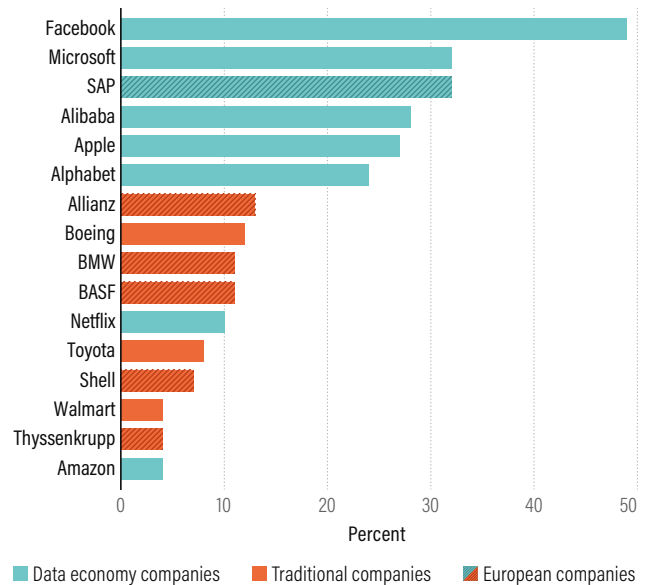
transactional platform firms such as Alibaba and Booking. However, revenue per employee in Europe's leading industrial firms such as Volkswagen and Siemens are even lower (Figure 3.8). Among transactional platform companies, Amazon's efficiency and profitability is relatively low. For instance, Amazon's overall operating margins (4 percent) are lower than Boeing (12 percent), BMW (11 percent) and Toyota (8 percent). Netflix, a subscription-based online video-streaming platform, is also characterized by a relatively low operating margin of about 10 percent (Figure 3.9).

**FIGURE 3.8** Revenues per employee are far higher for platform companies, 2018



Source: Fraunhofer (2019).

**FIGURE 3.9** Operating margins of the top platform companies are higher than in traditional companies from different industries, 2018



Source: Fraunhofer (2019).

Note: Apple's Products and Services segments are reported as gross margins (and not operating margins).

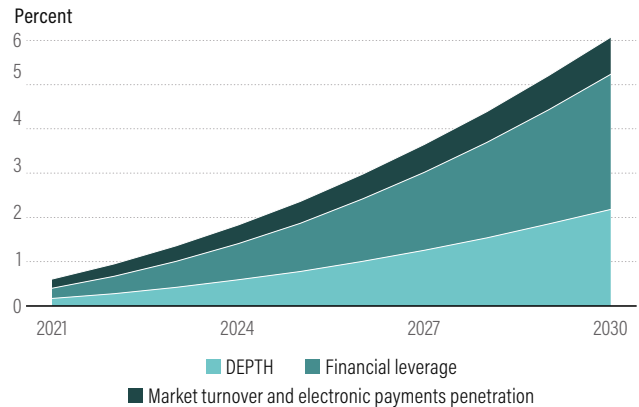
Differences in the efficiency and profitability of transactional platform firms may be attributable to the extent to which the platform function per se is the core business. The operating margins of Amazon are significantly lower than those of Alibaba because its 'traditional' ecommerce business — where it acts as a retailer itself — accounts for a large proportion of sales. However, Amazon is growing in areas where the company can achieve higher margins as a platform operator. For example, Amazon Web Services (AWS) recorded an operating margin of 25 to 30 percent. The share of sales through third-party vendors on Amazon has also increased substantially from close to zero in 2000 to more than 50 percent in 2018. The low operating margin of Netflix, which produces or licenses content and offers it via a streaming service, may be explained by the lack of network effects because no third party can offer content on its platform and users do not benefit from higher numbers of other users (Fraunhofer, 2019).

The successful implementation of BDLT is likely to be associated with significant efficiency gains and market expansion, as illustrated by its application in the financial sector. BDLT-based payment systems lower transaction costs by reducing interest rate spreads,<sup>15</sup> broker and settlement commissions, and insurance premiums. Casey et al. (2018) find that blockchain could reduce costs by 30 percent, translating into savings of between US\$8 and US\$12 billion, for the top 10 banks alone.<sup>16</sup> Estimates from Europe's financial sector, more generally, suggest that BDLT will roughly halve transaction costs in segments such as payments, corporate banking and insurance. This, in turn, may increase the frequency of transactions, the amount of investments, the turnover in financial markets and the value of insured assets. Resulting cumulative market growth due to BDLT implementation is projected to range from 34 percent in retail banking to 70 percent in insurance, with the majority attributable to growth at the intensive (existing market)<sup>17</sup> rather than extensive (new customers) margin (Padilla et al. 2019).

Over time, the successful implementation of BDLT is likely to translate into economic gains in Europe. Based on the effects of changes in the parameters of financial development on EU GDP,<sup>18</sup> it is estimated that BDLT-enabled cumulative growth of EU GDP from 2021 to 2030 will be 6.3 percent. The estimated impact of BDLT implementation on GDP is largely attributable to the financial depth and leverage parameters, which are projected to experience a cumulative rate of growth, respectively, of 15 and 23 percent over the next decade. The contribution of market turnover and electronic payment penetration to BDLT-enabled GDP growth is estimated to be negligible (Figure 3.10).

Several examples across Europe also highlight the efficiency gains associated with the implementation of BDLT. SatoshiPay’s distributed ledger infrastructure allows for micropayments that are fast (3- to 5-second settlement), secure and low cost (lower variable with no fixed fee) compared with regular payments. In 2018, the user base of SatoshiPay comprised about 2,000 transactions per month, primarily in the publishing business. Then, in 2019, SatoshiPay announced a partnership with Axel Springer—the largest European digital publisher—of which 60 percent would be linked to digital media activities.<sup>19</sup> Similarly, SettleMint’s toolkit, which allows for the easy and rapid development of BDLT applications, has reduced the cost of financial transactions by almost 80 percent through the removal of intermediaries and back-office needs.<sup>20</sup> SettleMint is active across sectors, such as through a tokenized system of incentives for future energy purchases with Elia and unlocking the potential of Proximus’s (Belgian telecom group) data monetization with its corporate clients.

**FIGURE 3.10** Cumulative BDLT-enabled GDP growth in Europe, 2021–30



Source: Padilla et al. (2019).

Note: BDLT = blockchain and distributed ledger technology; GDP = gross domestic product.

## Is the use of transactional technologies associated with reshoring to, or less offshoring from, Europe?

There is evidence that the use of ecommerce platforms has allowed firms to access international markets by reducing the costs of matching buyers and sellers all over the world. For example, Lendle et al. (2016) find that the impact of distance on cross-border trade flows across 61 countries and 40 product categories is about 65 percent smaller for eBay transactions relative to total international trade. Firms in Europe have benefited too. For example, the Enterprise Europe Network (2018) estimate that 40 percent of European e-shoppers are buying from France and almost 30 percent of Italy’s ecommerce sales in 2016 were abroad. While many of these transactions replace traditional offline trade flows, ecommerce on digital platforms could increase trade in manufactured goods by about US\$1.3 to US\$2.1 trillion by 2030 (McKinsey Global Institute, 2019).

The emergence of digital labor market platforms has also enabled a new form of online outsourcing for IT and IT-enabled businesses. Digital platforms help match buyers and sellers of online freelancing services, just as traditional ecommerce does for the trade in goods. The objective information available online, combined with the ability to send the output of the work (typically data or software code) over long distances, helps workers who are far from the buyer. Compared with traditional outsourcing from firms, hiring remote foreign freelancers also casts a wider net of workers, time zones, nontraditional schedules, and flexibility with hiring/firing regulations. Upwork, which is the world’s largest such platform, had 14 million users from over 100 countries in 2017 and processed more than US\$1 million in freelancer earnings. Other similar platforms include oDesk, and Freelancer. In 2016, the market size for online freelancing was estimated at US\$4.4 billion (Kuek et al., 2015).

This online outsourcing reflects arbitrage based on labor costs such that buyers and sellers are concentrated, respectively, in high-income and low- to middle-income countries. A computer programmer or accountant in India earns a fraction of the salary of a computer programmer in the United States and Europe (Baldwin, 2019). It is therefore

not surprising that the majority of global demand for online outsourcing services comes from just four countries—Australia, Canada, the United Kingdom, and the United States. The United States is the dominant employer country, with a market share of 52 percent, but employers elsewhere are catching up and growth was fastest in Europe (excluding the United Kingdom) between 2016 and 2017. At the same time, half the population of online freelancers is based in India, Bangladesh and Pakistan. This suggests that online platforms with standardized information disproportionately benefit workers from developing countries (Agrawal, Lacetera and Lyons, 2016).

Nonetheless, online freelancing could be associated with cultural similarities or the lack thereof. The importance of language considerations is reflected in patterns of online outsourcing—much of global demand comes from countries that are almost exclusively Anglophone, while the suppliers are in South Asia where English is the preferred language for business transactions. Using data from online labor markets, Lyons (2017) shows that cross-cultural international teams can be less productive because of communication challenges, while Ghani, Kerr and Stanton (2014) show that employers in the Indian diaspora are more likely to hire Indians online. For a product with zero shipping costs (visiting websites), people are more likely to visit websites from nearby countries than from faraway countries, especially in taste-dependent product categories (Blum and Goldfarb, 2006; Alaveras and Martens, 2015).<sup>21</sup>

The use of blockchain in trade finance can strengthen transactions in global value chains. Letters of Credit (LC), which provide the commitment of a financial intermediary to pay a third party in the possible event of default from its client, are at the core of the trade finance system. The process involves an assessment of the creditworthiness of the trading partner, as well as the financial intermediaries linked to both parties.<sup>22</sup> The issuance of a LC generally entails a back-and-forth and paperwork spreads over multiple stakeholders (applicant, issuing bank, advising bank, recipient) through multiple reviews to ensure coherence of transactions along the value chain. The data generated and exchanged along this process are currently siloed in the information system of each organization, but when shared through a trusted ledger can accelerate processes. This is particularly relevant for cross-border payments, which currently require longer settlement times and higher costs.

The application of blockchain in commodity trade finance provides an illustration of this trade-enhancing effect. The success of Komgo—a DLT-based network solution started in Geneva, Switzerland—is reflected in the operational launch of two key pilots for crude oil and soybean transactions. For example, clearing transactions of 60,000 tons of soybean between the United States and China on blockchain was reduced to five days in a process that usually takes 20 to 25 days (AGEFI Commodities, 2019; Wass, 2019). Independent trading companies involved in the pilots estimate that blockchain could soon reduce operational costs by up to 30 percent (AGEFI Commodities, 2019). Benefits were estimated along the full chain to be worth 30 to 40 percent in cashflow gains, with an expected cost reduction of 20 to 50 percent and possibly more at the industry level (Consensys, 2019).

## TRANSACTIONAL TECHNOLOGIES AND MARKET INCLUSION IN EUROPE

### Is the use of transactional technologies biased toward large firms?

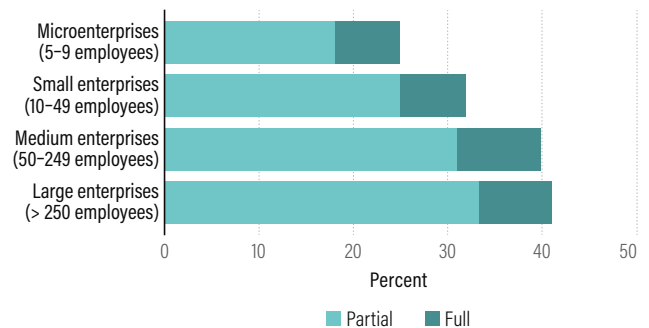
Digital platforms that support transactions have enabled market entry and growth for SMEs. The European Commission reports that an estimated 1 million businesses in the EU are using online platforms to sell goods or services. And around half of the SMEs selling via online platforms report selling internationally (EC Online Platforms Digital Single Market, accessed September 12, 2019). Online platforms can provide new and small firms with immediate opportunities to sell their products and services to a wider potential consumer market (OECD, 2019). Airbnb, for instance, is set up as a decentralized marketplace, enabling individuals or small firms to make their products or services available to a wide range of buyers.



Online platforms disproportionately benefit smaller firms by reducing verification costs, which enable market entry. Small firms can be unfamiliar to potential customers and online platforms can, through their brand and reputation, enable market exchange in the presence of asymmetric information about the quality and trustworthiness of these suppliers. Rating systems that signal product quality on these platforms further enhance buyers' trust in unfamiliar suppliers. Better-rated sellers on eBay have higher prices and higher revenues (Melnik and Alm, 2002; Livingston, 2005; Houser and Wooders, 2005; Lucking-Reiley et al., 2007) and sellers with low ratings exit from eBay's platform (Cabral and Hortacsu, 2010). Similarly, comparing changes in reviews on Amazon relative to Barnes and Noble, Chevalier and Mayzlin (2006) demonstrate that positive reviews lead to higher sales.

The shares of small- and medium-sized firms using digital platforms in the EU, at 32 and 39 percent, respectively, are not notably different from those of large firms (Figure 3.11). Furthermore, the use of digital sales is associated with a smaller productivity gap between large and small firms. In accommodation services, the sector where this technology is most widespread, countries with a higher share of firms that use online sales are also characterized by a smaller gap in labor productivity between large and small firms. For example, labor productivity in large firms is more than double that of small firms in Latvia, where the share of firms that use online sales is less than 50 percent. In contrast, labor productivity in large and small firms is about the same in Estonia, where the corresponding share was more than 70 percent. However, there is no such association, on average, in sectors that use this technology the least—construction, real estate and professional services (Figure 3.12). This result is consistent with the fact that scale-neutral digital platforms favor small firms by reducing the fixed costs of entering new markets.

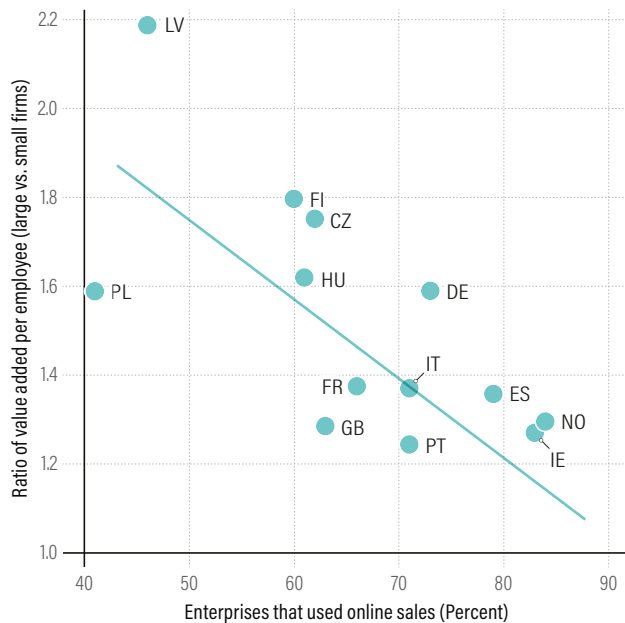
**FIGURE 3.11** The share of SMEs using digital platforms in the EU is not very different from large firms, 2019



Source: EIB-WBG background paper by Cathles, Nayyar and Rückert (2020).

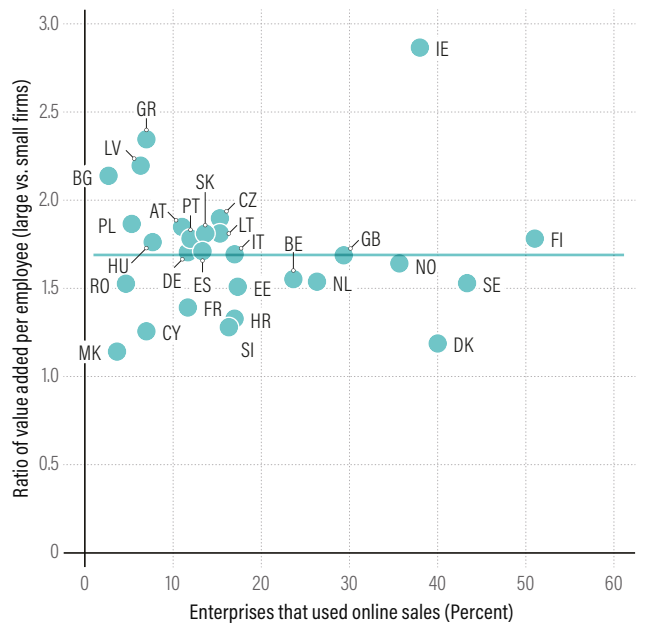
**FIGURE 3.12** The use of online sales enables small firms to catch up with the performance of large firms

a. The use of online sales is associated with a smaller performance gap between large and small firms in accommodation services where the technology is most widespread, 2016



Source: Authors' calculations based on Eurostat.

b. There is no association between the use of online sales and the performance gap between large and small firms in construction, real estate, and professional services where the technology is least widespread





At the same time, transactional platforms themselves are prone to the emergence of a few dominant players. The replication cost of digital platforms is zero, i.e., their services can be consumed by one person without reducing the amount or quality available to others. This enables platforms to serve many customers quickly. Furthermore, massive amounts of accumulated user data can enable platform companies to steer users to their own advantage via filtering, framing, ordering results, advertisements, nudging, and so on (Stigler Committee on Digital Platforms, 2019). As a result, a few companies often dominate the market. Take the example of Uber, Lyft and Via among ride-sharing platforms, Amazon, Walmart and eBay among ecommerce platforms, and Airbnb, Kozaza and Couchsurfing among accommodation platforms. Network effects are perhaps less important than with social networking platforms, but users may still benefit from other consumers through customer ratings and reviews.

The dominant position of Amazon, for example, is reflected in its market capitalization, cash reserves, and acquisitions. Amazon, at US\$917 billion, had the second-largest market capitalization of all platform companies in the S&P 500 – second only to Apple. High profits have also resulted in enormous cash reserves which, in turn, are frequently used for acquisitions (Fraunhofer 2019). The acquisition of Whole Foods Market by Amazon for US\$13.7 billion is a case in point.<sup>23</sup>

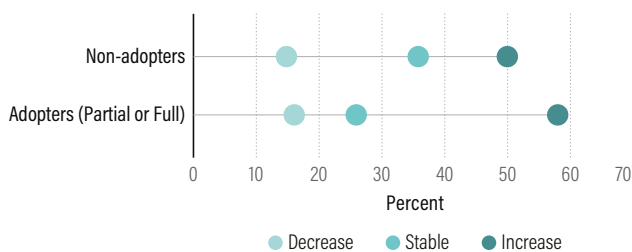
Blockchain is also a promising technology for reducing verification costs. Blockchain enables the exchange of value between two distant untrusting parties without the need for an intermediary. Transaction attributes, or information on the agents involved, can be cheaply verified if stored on a distributed ledger. This means that trust in an intermediary could be replaced by trust in the underlying code and rules that define how the network can reach agreement (Catalini and Gans, 2016). Such low-cost verification is particularly beneficial for small firms that often lack access to financial intermediaries (Böhme et al., 2015; Catalini and Tucker, 2017).

## Is the use of informational technologies associated with fewer jobs?

Most leading platform firms do not directly generate as many jobs as leading firms in traditional industries. While Germany’s DAX-30 companies employ around 4 million people worldwide, Apple, Amazon, Alphabet (Google), Facebook and Microsoft – which generate roughly the same amount of profits – together employ only about 1 million people worldwide (Fraunhofer, 2019), with around three-quarters in North America (Evans and Gawar, 2016).<sup>24</sup> Amazon, a transactional platform, accounts for almost two-thirds of these 1 million jobs due to its comparatively labor-intensive business as an online retailer with a large logistics infrastructure. In fact, Amazon is the second-largest employer in the United States after Walmart. Most platform companies, however, can scale up very quickly without hiring new employees or building new factories compared with more traditional business models. The infrastructure required, such as computing or storage, can be flexibly added as required during the growth process.

**FIGURE 3.13** Trends in employment growth in the EU over the past three years

By platform adoption, 2019



Source: EIB-WBG background paper by Cathles, Nayyar and Rückert (2020).

Note: Firms are weighted with value added.

In the broader universe of firms, the association between the use of platform technologies and employment growth in Europe is somewhat ambiguous. Recent EIB survey data show that about 60 percent of firms that partially or fully implemented B2C platforms in their business experienced an increase in employment growth over the past three years, compared with 50 percent of firms that did not adopt these technologies. Similarly, a little less than 15 percent of firms among both adopters and non-adopters experienced a decline in employment growth (Figure 3.13).<sup>25</sup>

Digital platforms may displace labor if they make incumbent service providers exit the market, but evidence suggests that they create more jobs than they destroy. Based on firm-level

data from the United States and nine European countries,<sup>26</sup> Bailin et al. (2019) find that sharing economy platforms, such as Uber and Airbnb, are associated with a decline in employment and wages among incumbent service providers. However, the analysis does not study the entry of new service providers. In the United States, ‘non-employers’ in the ground passenger transportation sector grew by almost 250 percent from 2010 to 2016. Considering that there were almost no Uber drivers in 2012 and 465,000 Uber drivers in 2015, this suggests that job creation in the sector can indeed be attributed to online platforms (Abraham et al., 2018). Similarly, Mandel (2017) finds that ecommerce created 400,000 jobs, while retail jobs in brick-and-mortar firms declined by 140,000 between 2007 and 2017 in the United States. ‘Aggregator’ platforms, which connect consumers to service providers (e.g., Booking.com, TheFork), are associated with higher employment and no wage decline among incumbent services providers (Bailin et al., 2019).

Furthermore, online freelancing platforms may reduce friction in the labor market by matching employers and workers. Based on all projects posted publicly to five of the largest English-language online work platforms — Freelancer.com, Guru.com, Mturk.com, Peopleperhour.com, and Upwork.com — Kässi and Lehdonvirta (2018) find that the market grew by 25.5 percent from July 1, 2016, to June 30, 2017.<sup>27</sup> Software development and technology work is the biggest occupation category in the market, and also among those that grew the fastest, at 37 percent between 2016 and 2017. The next biggest category, creative and multimedia, grew by 21 percent. The third-largest category, clerical and data entry, did not grow at all in net terms.<sup>28</sup> Professional services such as accounting, business consulting, and legal advice grew by as much as 43 percent over the year, but still represent less than 3 percent of the overall online gig economy (Figure 3.14).

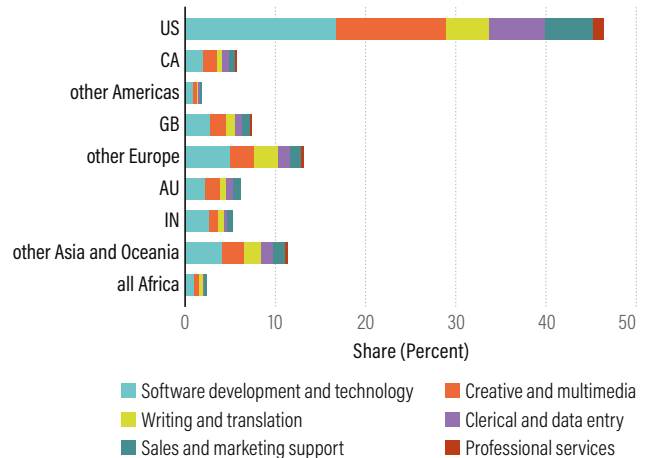
One-eighth of the global population of online freelancers are estimated to be based in the United Kingdom and the United States (Baldwin, 2019). In terms of the dollar inflow from work contracted via digital labor platforms, Belarus, Poland, the Russian Federation, Ukraine and the United Kingdom stood out among European countries (Graham et al., 2017).<sup>29</sup> The other big emerging suppliers in Europe, particularly after the size of the labor force is taken into account, include Romania and Serbia. In all European countries, the majority of work commissioned via digital labor platforms was done by foreign employers, although the United Kingdom and France have a relatively large portion (albeit, still less than half) of work commissioned by buyers within those countries (Graham et al., 2017).

Beyond online freelancing, lower-skilled gig economy work linked to ‘crowd work’ platforms often compensates for increases in unemployment elsewhere in the economy. Huws et al. (2017) estimate that around 22 percent of people in Italy and 9 percent of people in Germany and the United Kingdom have engaged in crowd work. Similarly, Szczepański (2018) estimates that the United Kingdom, Germany and France are the EU countries with the greatest number of app-related jobs, while Finland, the Netherlands, Sweden and Denmark all have a higher density of app-related jobs than the United States, after accounting for population size. People typically engage in ‘crowd work’ to supplement their income from a primary occupation (Abraham et al., 2018). In the United States, workers consider online labor markets as a substitute to offline work, especially in periods of low local labor demand (Borchert et al., 2018). Evidence suggests that demand fluctuations lead to changes in the quantity (labor) supplied rather than changes in prices on two-sided digital platforms — in the case of cleaning, moving, and simple home repair services (Cullen and Farronato, 2016) and peer-to-peer ride- and house-sharing (Hall, Kendrick and Nosko, 2016; Farronato and Fradkin, 2018; Zervas, Proserpio and Byers, 2017).

Nonetheless, there are concerns about the quality of such gig economy jobs. Unlike full-time international freelancers that make more than their peers who have traditional jobs (Baldwin, 2019), the share of ‘own account’

**FIGURE 3.14** Software development and technology work is the biggest occupation category in the market for online freelancing

Demand for online work, by country and sector, 2018



Source: Online Labour Index.

workers (people working in the gig economy) making less than the minimum wage in Europe ranges from around 3 percent in Portugal to more than 30 percent in Slovakia (OECD, 2019). There might also be nonpecuniary concerns such as unstable contractual arrangements, working conditions, the lack of employment-linked social security, and the ratio of paid to unpaid work (Huws et al., 2017).

## TRANSACTIONAL TECHNOLOGIES AND GEOGRAPHIC CONVERGENCE IN EUROPE

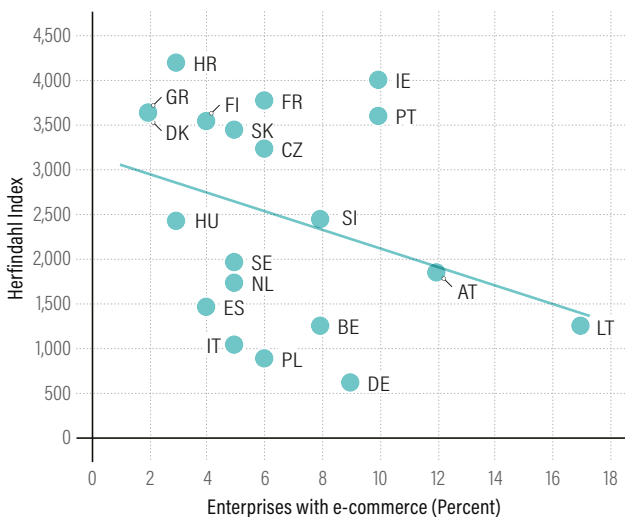
### Is the use of transactional technologies associated with a higher spatial concentration economic activity in certain European regions?

The use of digital transactions through ecommerce platforms is associated with lower spatial concentration in Europe. In the information and communication services subsector, where this technology is most widespread, economies with a higher share of firms that use ecommerce platforms for digital transactions are characterized by a lower Herfindahl Index of Concentration, based on the number of workers at the NUTS2 level (Figure 3.15). For example, the regional concentration of economic activity in Greece, where 2 percent of firms used ecommerce platforms, was more than three times that in Lithuania, where the corresponding share was close to 20 percent. However, there is no such association between the use of ecommerce platforms and spatial concentration in sectors that use this technology the least—construction, real estate, and professional services. This result is consistent with the fact that ecommerce platforms might enable firms in more remote areas to access external markets through their transport and logistics supply chain. Nonetheless, other evidence

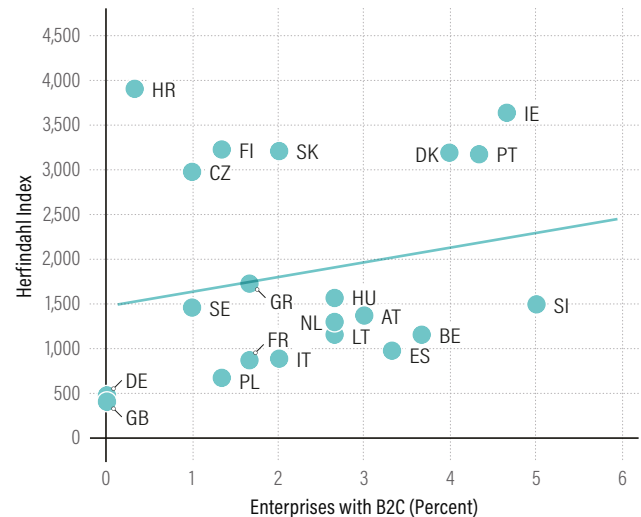
**FIGURE 3.15** The use of ecommerce platforms is associated with geographic convergence in Europe

Share of firms (%) that used an ecommerce platform to sell online and the Herfindahl Index of Concentration at the NUTS2 Level, 2016

a. The use of ecommerce platforms to sell online is associated with lower spatial concentration the information and communication services sector where this technology is widely used



b. There is no association between the use of ecommerce platforms to sell online and the spatial concentration in construction, real estate, and professional services where this technology is least widespread



Source: Authors' calculations based on Eurostat.

Note: NUTS = Nomenclature of Territorial Units for Statistics.

indicates that trust remains easier locally. Hortacsu, Martinez-Jerez and Douglas (2009) show that same-city sales on eBay and MercadoLibre (a Brazilian electronic commerce platform) are disproportionately high, likely because products are observed and delivered in person.

Digital platforms make remote service delivery possible for a wider range of services tasks. The internet has reduced the need for a task-specific workspace, thereby increasing the prevalence of ‘telecommuting’ (Autor, 2001; Gaspar and Glaeser, 1998). Therefore, working remotely is not new, but the scope of what can be transacted through online platforms is expanding. The low search costs associated with online platforms make it more feasible for more workers from more locations to match with potential buyers. Examples of online platforms that contract work that is executed remotely include Upwork, Freelancer.com, mTurk and Fiverr (Wood et al., 2019). Some seventy million workers are estimated to have worked remotely via an online platform around the world. These possibilities could serve to counteract trends in agglomeration and concentration of production.

Nonetheless, evidence is indicative of the regional concentration of ‘crowd work’ in Europe. Based on a survey and in-depth interviews of gig workers in Austria, Germany, Italy, the Netherlands, Sweden, Switzerland and the United Kingdom, Huws et al. (2017) find some regional concentration. Crowd work is concentrated in the west of the Netherlands, around Vienna in Austria, around London in the United Kingdom, in Zurich in Switzerland, and around Rome or in the north of Italy. There are a few exceptions. Crowd work seems to be evenly spread throughout Germany and, while there is slight concentration in Sweden, it is not around Stockholm (Huws et al., 2017).

This regional concentration of online freelancing may be attributable to geography-specific tastes and social networks. Sinai and Waldfogel (2004) show that highly populated areas produce more digital content, and that because tastes are spatially correlated people in highly populated areas are particularly likely to go online. This geographic-specificity in tastes is also reflected in the consumption of digital goods such as music (Ferreira and Waldfogel, 2013) and content (Gandal, 2006). Furthermore, much online behavior is social, and social networks are highly local (Hampton and Wellman, 2003). Tracking investment data for Sellabrand, a Netherlands-based crowdfunding platform for musicians, Agrawal et al. (2015) find that early funding tends to come from local supporters who the musicians knew prior to joining the crowdfunding platform, although later funding often comes from strangers as a musician gains prominence on the website.<sup>30</sup>

This concentration of ‘gig economy’ work may also be attributable to tasks that need to be delivered locally or remote tasks being skill-biased. Work that is transacted via online platforms, but delivered locally, could increase spatial concentration in major urban centers. Take, for example, ride-sharing platforms such as Uber, Lyft, Blablacar and Didi Kuaidi, or personal services platforms such as TaskRabbit and Care.com, where a service provider must be physically present in the same location as the consumer. Given that the demand for transportation and household services will likely be higher in major cities with higher population densities, this could induce migration to these areas. The same may be true with the demand for household services generated by accommodation platforms, such as Airbnb, Kozaza and Couchsurfing in tourist hubs. For tasks that can be delivered remotely, such as computer programming through oDesk and Freelancer, a concentration in hubs may reflect agglomeration effects, particularly with respect to skilled workers in local labor markets.

## Is the technology itself concentrated in some European countries and regions?

There is little evidence of catch-up in the use of transactional platforms across countries, which suggests that diffusion has been greater within countries. Countries with the highest and lowest shares of firms that used a B2C website or app to sell online in 2014 experienced growth rates in this share subsequently between 2014 and 2018 that were not very different from one another.<sup>31</sup> These included the Czech Republic, Germany, Sweden, the Netherlands and Norway at the top end of the distribution, and Romania, Bulgaria, Italy and Macedonia at

**FIGURE 3.16** There is a lack of convergence in the use of transactional technologies between leading and lagging countries

Share of enterprises that used a B2C app or website to sell online (Percent)



Source: Europe 4.0 team calculations, using data from Eurostat.

Note: B2C = business-to-consumer; EU = European Union.

the bottom end of the distribution in 2014 (Figure 3.16). For example, in 2014, the Czech Republic had among the highest share of firms that used a B2C website to sell online, at 20 percent, and Romania among the lowest, at 5 percent. Yet, the Czech Republic also experienced a 5 percent increase in this share between 2014 and 2018, while Romania experienced a 5 percent decline.

Digital platform companies themselves tend to gravitate to the big cities. Evans and Gawar (2016) show that the 27 European digital platform enterprises are spread across 10 countries: the United Kingdom (9), Germany (5), Russia (3), France (2), the Netherlands (2), Sweden (2), Ireland (1), Israel (1), Luxembourg (1) and Norway (1). Eight out of the nine platforms in the United Kingdom are in London, three out of five platforms in Germany are in Berlin, two out of three platforms in France are in Paris, and both platforms in the Netherlands are in Amsterdam. Similarly, Szczepański (2018) finds that app developers in Europe are concentrated in major capital cities or commercial centers, namely London, Paris, Madrid, Berlin, Helsinki and Barcelona. The author shows that, if weighted by population, Helsinki has the second-highest density of app developers in the world, after San Francisco. Agglomeration effects, which are greater for technology creation than for adoption, mean that cities disproportionately benefit.

BDLT-based platforms, which provide low-cost solutions to increase financial inclusion, are likely to simplify access to financial services in regions with less developed financial systems. On the supply side, they can be relatively easier to implement than traditional financial services infrastructure, unlike in leading European regions where changes in existing infrastructure may be more expensive to implement. On the demand side, hitherto unbanked populations may adopt BDLT financial technologies faster than more conservative and aging populations in advanced regions, where cultural resistance to change may slow down the implementation of BDLT.

The economic effects of BDLT implementation may therefore be much more significant in East Europe where financial systems are weaker than in West and North Europe.<sup>32</sup> For example, SMEs in Romania have very limited access to financing as banks prefer to invest in public debt. With BDLT implementation, interest rates may decline, which would allow directing more resources to risky assets, including loans to SMEs. It is estimated that by adding to the investment, corporate and retail banking markets, respectively, by 30, 10 and 30 percent, the application of BDLT will result in an 8.0 percent increase in Romanian GDP by 2030, compared with a 6.2 percent BDLT-enabled increase in European GDP (Padilla et al. 2019).

## CONCLUSION

The share of firms that meet even a minimum threshold of selling online in Europe is far from universal and penetration rates remain uneven. The share of firms selling at least 1 percent of their turnover online in any given European country in 2018 was, at most, about one-third. The share of firms that used a B2C website or app to sell online in Europe is even lower and those that use an ecommerce marketplace to sell online is lower still. While the EU-14 North and Central countries feature prominently among those where diffusion

of these technologies is greatest, Serbia, Bosnia and Herzegovina, the Czech Republic and Lithuania are also among the top adopters of B2C platforms.

Europe is also not home to the leading digital transactional platforms. Think Amazon, eBay, Alibaba, and Booking. Revenue per employee and operating margins in these large platform companies are notably higher than Europe's leading manufacturing sector firms, such as Volkswagen and Siemens.

The average service provider in Europe has experienced bigger multifactor productivity increases in countries with high online platform development vis-à-vis the average service provider in countries with low online platform development. Furthermore, the widespread use of ecommerce platforms has allowed firms in LMICs to access international markets through reducing the costs of matching buyers and sellers all over the world. Similarly, the emergence of digital international labor market platforms has enabled a new form of online outsourcing for IT and IT-enabled businesses.

The successful implementation of blockchain and distributed ledger technology (BDLT) is also likely to be associated with significant efficiency gains by reducing transaction costs. The use of blockchain in trade finance, partly pioneered in Europe, can also strengthen transactions in global value chains. Letters of Credit, which provide the commitment of a financial intermediary to pay a third party in the possible event of default from its client, are at the core of the trade finance system. The relevant information when shared through a trusted ledger can accelerate processes by reducing the approval times needed from financial intermediaries.

Digital platforms that support transactions have enabled market entry and growth for SMEs. Furthermore, the use of online sales in Europe is associated with a smaller productivity gap between large and small firms. This reflects the fact that scale-neutral digital platforms disproportionately favor small firms by reducing the fixed costs of entering new markets related to search, verification, and distribution networks. At the same time, the zero cost of servicing an additional consumer and access to big data make transactional platforms themselves prone to being dominated by a few players. The dominant position of Amazon and Alibaba as platforms that enable market exchange is a case in point.

The use of ecommerce platforms has reduced spatial concentration in Europe. This reflects the fact that ecommerce platforms might enable firms in more remote areas to access external markets through their transport and logistics supply chain. Digital platforms also make remote service delivery possible for a wider range of services tasks. Nonetheless, evidence is indicative of regional concentration of online freelancing in Europe. This may be attributable to geography-specific tastes and social networks, the local gig economy of driving and delivery work, and specialized skills such as programming associated with the online freelancing. Furthermore, there is little evidence of catch-up in the share of firms using digital matching platforms across European countries, which suggests that diffusion of transactional technologies has been greater within countries.

As a promising technology for reducing verification costs, blockchain too is likely to benefit smaller firms and lagging regions disproportionately. By enabling the exchange of value between two distant untrusting parties without the need for an intermediary, blockchain will likely benefit smaller firms with limited access to financial services or regions with less developed financial systems. BDLT-based investment platforms therefore provide low-cost solutions to increase financial inclusion.

Digital platforms can displace labor among traditional incumbents in an industry, but they also create new jobs, including by facilitating the matching process. Ride-sharing platforms are considered disruptive for taxi drivers, but they create more job than they destroy. There are other platforms, such as Booking and TripAdvisor, that connect consumers to service providers without disrupting the latter by aggregating information. Furthermore, online freelancing and 'crowd work' platforms may reduce friction in the labor market by matching employers and workers. The United Kingdom, Ukraine, Russia, Poland, Belarus, Romania and Serbia are among the leading European countries in terms of supplying online freelancers.



## Notes

1. The platform owner provides the technological foundation for external actors to interact and execute transactions. But external forces can enhance the value of the platform too. Suppliers produce complementary goods or services and compete for users. Users express demand for the platform leader's service, as well as the complements.
2. The Enterprise Europe Network (2018) estimates that the market value of ecommerce in Europe is €455 billion and grew by more than 13 percent from 2014 to 2015.
3. Clarifications were recently brought to "blockchain myths" such as concerning the so-called "immutable" and "trust-free" nature of blockchain (see Hileman and Rauchs, 2017; or Carson et al., 2018)
4. See IDC (2018) at <https://www.idc.com/getdoc.jsp?containerId=prEMEA43543718>
5. Based on respondents in the services and infrastructure sectors, about 40 percent of firms in the United States report having partially or fully adopted B2C platform technologies, compared with about 33 percent in the EU-28.
6. France and the United Kingdom are estimated to have €72 billion and €157 billion, respectively, in ecommerce sales, compared with Poland and Croatia with €10 billion and €315 million, respectively.
7. Growth in each market segment reflects growth owing due to BDLT penetration (all other factors are assumed constant). The deflators (related to BDLT implementation) correspond to the cost reduction estimates for each segment.
8. The authors noted that many platform companies in Africa and Latin America did not meet the US\$1 billion market value threshold and were hence excluded.
9. This perhaps reflects a tendency that consumers tend to prefer domestically developed apps (Caribou Digital, 2016).
10. Micropayments refer to small instantaneous ad-hoc payments (less than €1). See also <https://www.forbes.com/sites/forbesdallas/council/2019/04/25/are-micropayments-the-future-of-online-transactions/#7d82df767202>
11. The authors develop a proxy for online platform development based on Google searches containing part of the name of 50 relevant platforms grouped within industry and year (2004–17) for each country.
12. However, these productivity gains in incumbent service provider firms drop sharply if a single online platform dominates.
13. This controls for country- and industry-specific factors.
14. They identified 20 books and 20 CDs, half of which were bestsellers and half of which were randomly selected among titles popular enough to be sold in most offline stores.
15. Difference between deposit and loan interest rates.
16. These figures do not incorporate the opportunity cost that is incurred by institutions that must lock up capital for long periods of time until trades are settled.
17. Based on elasticities from the literature (Chiu and Hill, 2015; Martín-Oliver, 2011; Dick, 2007; Moody's analytics report, 2016; European Commission, 2012).
18. Moody's (2016) estimate of the elasticity of GDP with respect to electronic payments penetration is 0.18.
19. Source: <https://www.coindesk.com/satoshipay-integrates-blockchain-payments-for-major-european-publisher>
20. Source: [https://settlemint.com/settlemint-awarded-1-8-million-from-horizon-2020-instrument-grant/](https://settlemint.com/settlemint/2019/03/26/settlemint-awarded-1-8-million-from-horizon-2020-instrument-grant/), consulted on 03/08/2019
21. This internet-surfing behavior is consistent with the well-established empirical finding that bilateral trade decreases with distance (Anderson and van Wincoop, 2004).
22. The importer's bank will issue the LC to the exporter's bank.
23. Source: IG Group. Acquisitive Tech. URL: <https://www.ig.com/uk/cfd-trading/research/acquisitive-tech>
24. The authors note that there may be indirect employment effects not captured in these numbers. Furthermore, employment numbers could only be accessed for publicly traded firms, but only 10 percent of the digital platform companies in their database were private firms (Evans and Gawar, 2016).
25. This positive association between the adoption of platform technologies and employment growth is robust to the inclusion of country—and industry—specific factors, but becomes statistically insignificant when other firm characteristics, such as size, age, and exporting status are considered (Annex 3, Table A3.2).
26. Belgium, France, Germany, Hungary, Italy, Poland, Spain, Sweden and the United Kingdom.
27. The authors use application programming interfaces (APIs) and web-scraping techniques to periodically crawl the sample platforms and saving the list of job openings, the occupation and country. Changes between different crawls provide the measure for 'new vacancies' with the obvious limitation that any changes that may occur between crawls are not observed. They also track the traffic share of these platforms in relation to the overall market to ensure changes in market share don't confound the index.
28. Consists largely of the kind of work done on Amazon Mechanical Turk.
29. Based on anonymized data from March 2013 from one of the world's biggest digital labor platforms, in which 65,000 transactions occurred (in that month alone) drawing from 4.5 million registered workers to facilitate those transactions.
30. This colocation mirrors offline early stage venture capital which, prior to crowdfunding opportunities, had an element of proximity (the famous 20 minutes from the office rule).
31. These data are not available in a long time series.
32. For instance, World Bank data indicate that the private credit by deposit to GDP ratio was 34 percent in 2016 (decreasing during the past few years) compared with 75 percent in Germany and 170 percent in Denmark.



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# ANNEX 3

**TABLE A3.1** Relationship between B2C platforms and labor productivity, firm level, 2019

		B2C platforms
Digital technology		0.09* (0.06)
Sector	Manufacturing	N/A
	Construction	N/A
	Services	Reference Sector
	Infrastructure	0.35*** (0.05)
Adjusted R-Squared		0.15
N		4,932

Source: Cathles, Nayyar and Rückert (2020), using data from the 2019 EIBIS Survey.

Note: The dependent variable is log of labor productivity. The constant and country dummies are included, but not reported. Firms in different sectors were asked about different digital technologies, N/A indicates when a sector was not asked about a particular technology. The reference sector is also indicated. Firms in EIBIS are weighted with value added. All countries in the EU-28 and the United States are included in the regressions. Robust standard errors in parentheses.

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

**TABLE A3.2** Relationship between B2C platforms and employment growth, firm level, 2019

Digital adoption	0.32*** (-0.11)	0.14 (-0.12)	0.11 (-0.14)
Manufacturing			
Construction			
Services	Reference	Reference	reference
Infrastructure	0.20* (-0.11)	0.14 (-0.12)	-0.07 (-0.14)
Micro	Reference	Reference	Reference
Small		0.81*** (-0.12)	0.86*** (-0.14)
Medium		1.02*** (-0.13)	1.01*** (-0.16)
Large		1.23*** (-0.15)	1.25*** (-0.18)
Less than 5 years	Reference	Reference	Reference
5 years to less than 10 years		-0.18 (-0.39)	-0.49 (-0.38)
10 years to less than 20 years		0.12 (-0.36)	-0.04 (-0.31)
20 years or more		-0.36 (-0.35)	-0.49 (-0.3)

Exporter		0.27** (-0.12)	0.35** (-0.14)
Innovator		0.38*** (-0.13)	
Basic			Reference
Adopting			0.17 (-0.25)
Incremental innovators			0.43** (-0.19)
Leading innovators			0.55** (-0.26)
Developers			0.43** (-0.18)
N	6003	5786	4306
Pseudo R-squared	0.01	0.04	0.04

Source: Cathles, Nayyar and Rückert (2020), using data from the 2019 EIBIS Survey.

Note: The dependent variable logit is the increase in employment compared to 3 years ago = 1, and otherwise = 0. The constant and country dummies are included, but not reported. Firms in different sectors were asked about different digital technologies, N/A indicates when a sector was not asked about a particular technology. The reference sector is also indicated. Firms in EIBIS are weighted with value added. All countries in the EU-28 and the United States are included in the regressions. Robust standard errors in parentheses.

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .



## CHAPTER 4

# INFORMATIONAL TECHNOLOGIES

## INTRODUCTION

Informational technologies reduced coordination costs through the spread of computerization and the internet. The information and communication technology (ICT) revolution in the 1990s made it feasible to exploit the potential benefits of international production fragmentation, enabling the remote coordination of complex tasks at a relatively low cost (Batra and Casas, 1973; Dixit and Grossman, 1982; Jones and Kierzkowski, 1990, 2001). The resulting spread of global value chains (GVCs) meant specialization of a higher order whereby multinational firms combined high-tech ideas in advanced economies with low-wage workers in developing nations (Baldwin, 2011, 2016; Feenstra, 1998).

Newer ‘informational’ technologies use exponential growth of data to further reduce the cost of computing. The focus here is on business management software, such as enterprise resource planning (ERP) and customer relationship management (CRM), and advanced ICT services, such as cloud computing and big data analytics. Business management software is increasingly commonplace across a range of functions in firms, such as accounting, supply chain management, customer service, and human resources. Advanced ICT services emphasize the generation of data and their subsequent use in ‘smart’ production processes. For example, as cloud computing processes data for ‘smart’ factories, big data analytics use this real-time information to optimize production.

Machine learning, as an application of artificial intelligence (AI), is fundamentally altering the possibilities associated with computational power. Machine learning (ML) refers to a machine’s ability to observe its environment, learn, and articulate a strategy based on the knowledge and experience gained, without humans having to explain exactly how to accomplish all the tasks. While AI has existed for around 50 years, ML is a branch of AI that has particularly benefited from scientific advancements in deep learning, increased availability of higher-quality digital data, and improvements in algorithms (Brynjolfsson et al., 2019). The current diffusion

of image recognition, voice recognition, and machine translation is only just the beginning. This technology will continue to evolve, increasing its penetration and uptake in diverse industries (Craglia et al., 2018).

To the extent that informational technologies reduce coordination costs relative to labor costs, they can strengthen globally fragmented production. Newer ICT services reduce the costs of coordinating globally fragmented production by making it easier to track and monitor components as they move through the supply chain. Cloud computing, for example, can change the landscape of information storage and exchange, and enable better, more cost-effective coordination of globally fragmented production. Similarly, the analysis of large, fast-moving and varied streams of ‘big data’ can enable firms in GVCs to optimize complex distribution, logistics and production networks. However, the use of business management software could also result in the reshoring of back-office professional services to high-wage countries, many of which are in Europe, if the resulting process automation costs a fraction of offshore back-office workers located in low-wage economies.

Scale, infrastructure and skills requirements associated with informational technologies will determine the extent to which they concentrate economic activity in certain firms and regions. Business management software generally does not entail high fixed-cost investment and is therefore likely to provide a more level playing field for small firms. The same holds true for cloud computing which, in fact, substitutes for hardware. The skills requirements associated with these technologies too are unlikely to exceed what is needed to work with traditional ICT. Hence, lagging regions with a weaker skills base are unlikely to be disadvantaged. Big data analytics and ML, in contrast, are likely to be intensive in both scale and skills. Furthermore, to the extent that the use of informational technologies is predicated on broadband connectivity, the gap between leading and remote regions could widen.

The spread of computerization made it feasible for machines to replace labor in routine tasks that can be easily codified. This led to the hollowing out of middle-skill jobs, which comprised these ‘routine’ tasks, in Europe and the United States. Business management software that can reduce the importance of low labor costs in routine back-office processes will likely have the same impact. While informational technologies have traditionally displaced labor in routine manual tasks, ML is increasingly able to replace labor in routine cognitive tasks based on advances in cognition, and voice and image recognition.

This chapter sheds light on whether and how informational technologies are (re)shaping economic competitiveness, market inclusion and geographic convergence in Europe. The following analysis focuses on ERP and CRM software, cloud computing, big data analytics, and ML as the relevant technology set. This choice reflects their relevance for fundamentally reducing the cost of computing, as well as the constraints on data availability. Competitiveness is measured by productivity, trade and investment patterns. Market inclusion reflects the gap between large and small firms, and between labor and capital. Geographic convergence reflects differences in production outcomes, as well as technology diffusion and creation between European countries and regions at the NUTS2 level.

## THE TECHNOLOGY LANDSCAPE IN EUROPE

### How widespread is the use of informational technologies in Europe?

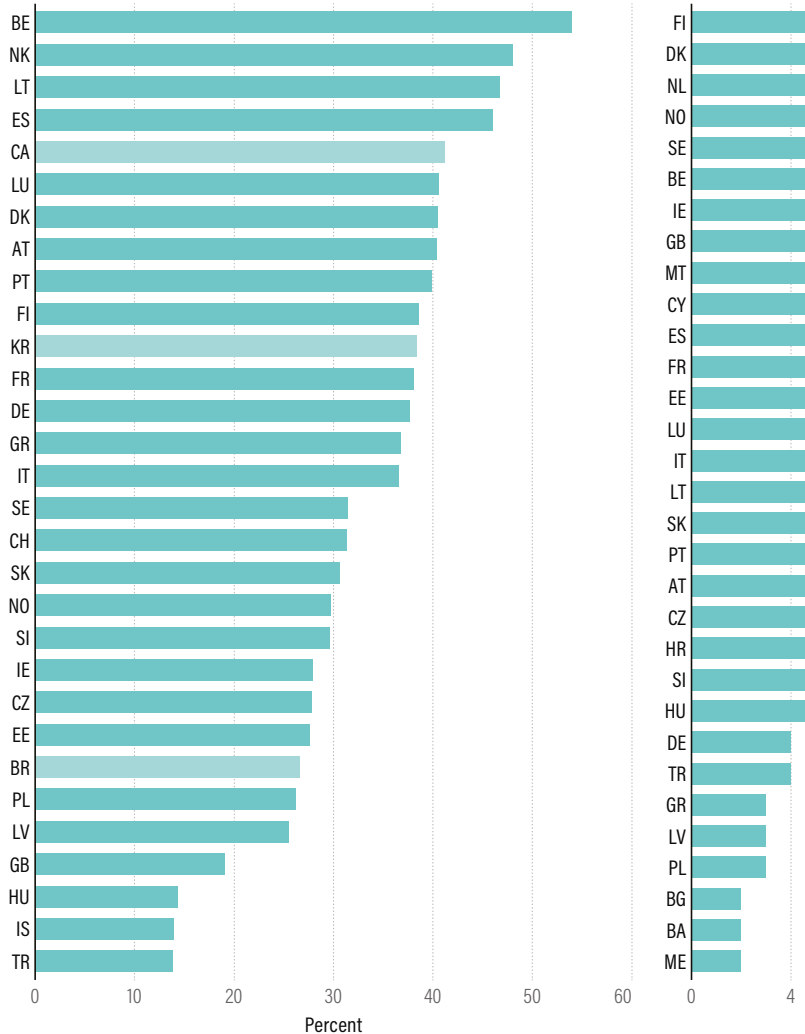
The share of firms using business management software in Europe is far from universal. Member countries of the EU-14 — North, South and Continental — feature prominently among countries with the highest share of firms using ERP software in Europe in 2018. These include Belgium (54 percent), the Netherlands (48 percent), Spain (46 percent), Denmark (41 percent), Austria and Portugal (40 percent), Finland (39 percent), France and Germany (38 percent), and Greece and Italy (37 percent). Outside Europe, 41 and 38 percent of firms, respectively, in Canada and the Republic of Korea used ERP software in 2018 (panel a, Figure 4.1). Norway



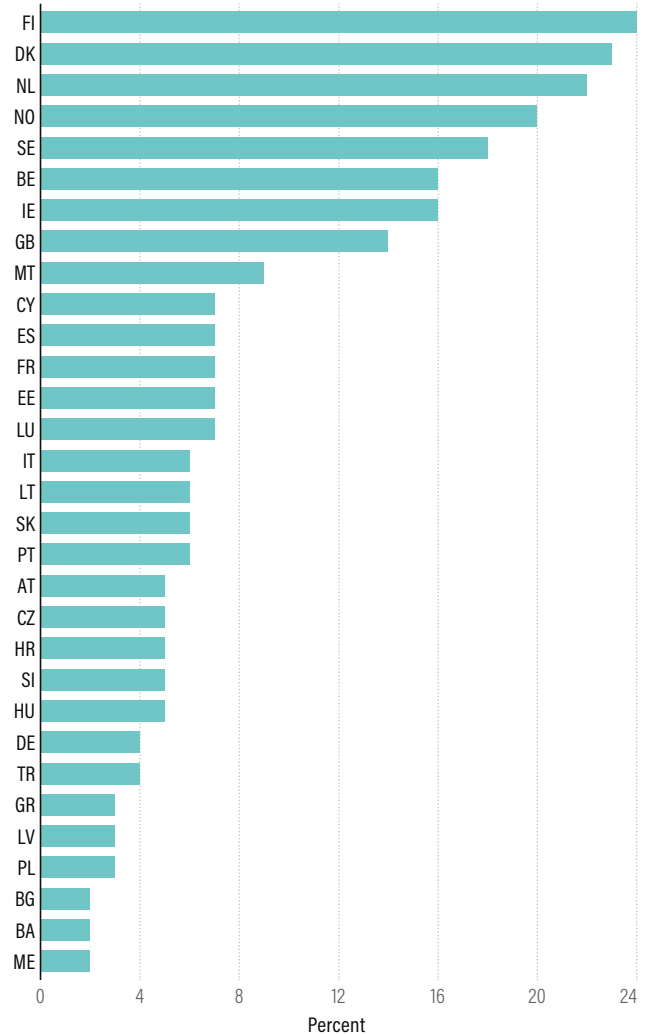
and member countries of the EU-14 North group stand out as having the highest share of firms using CRM software in Europe in 2018, although these adoption rates are considerably lower (panel b, Figure 4.1).<sup>1</sup> Outside of the EU-14, countries belonging to the EU-13 North group (Estonia and Lithuania) had the highest adoption rates for both ERP and CRM software.

**FIGURE 4.1** The share of firms using business management software in Europe is far from universal, but technology adoption rates are higher among countries in the EU-14 group

a. Share of firms that purchased ERP software, 2018



b. Share of firms that purchased CRM software, 2018



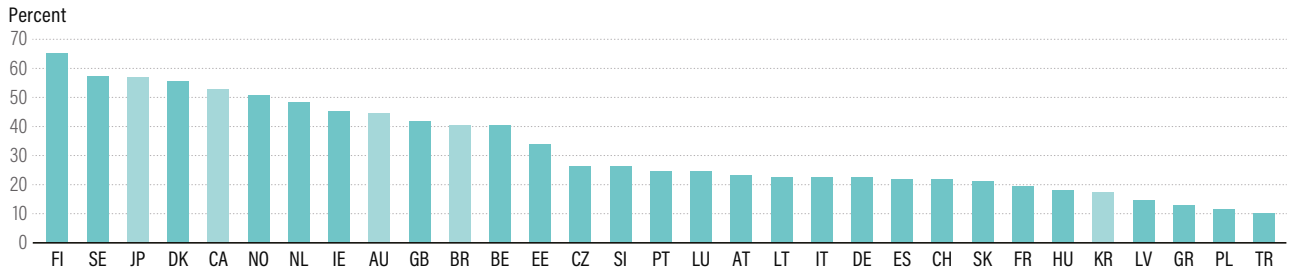
Source: Eurostat and OECD.

Note: CRM = customer relationship management; ERP = enterprise resource planning; EU = European Union.

The share of firms using cloud computing across Europe is notably higher, albeit not universal, and penetration rates remain uneven among different countries. Norway, the United Kingdom and EU-14 North group countries again feature prominently among those with the highest share of firms using cloud computing services in Europe in 2018. They include Finland (65 percent), Sweden (57 percent), Denmark (56 percent), Norway (51 percent), the Netherlands (48 percent), Ireland (45 percent), the United Kingdom (42 percent) and Belgium (40 percent). The share of firms using cloud computing in Germany (22 percent) and France (19 percent) was uncharacteristically low. Other countries, such as Greece, Hungary, Latvia and Poland, also lag considerably behind the frontrunners, with cloud computing penetration rates of less than 20 percent (Figure 4.2).

**FIGURE 4.2** The share of firms using cloud computing in Europe is also far from universal and technology adoption rates are again higher among EU-14 countries

Share of firms that purchased cloud computing services, 2018



Source: Eurostat.

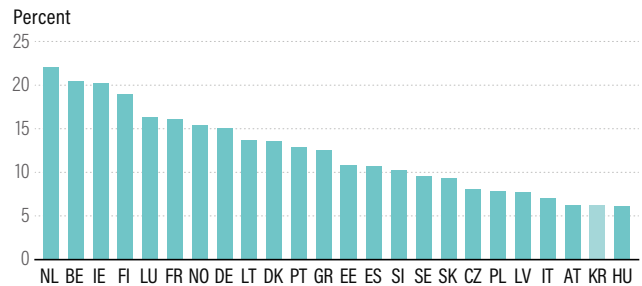
The share of firms using big data analytics is lower than for other informational technologies across Europe. Countries comprising the EU-14 North group feature prominently among those with the highest share of firms using big data analytics in Europe in 2018. These include the Netherlands (22 percent), Belgium (20 percent), Ireland (20 percent), Finland (19 percent), France (16 percent), Norway (15 percent), Germany (15 percent) and Denmark (14 percent). Outside the EU-14 group, Estonia and Lithuania had the highest adoption rates. The share of firms using big data analytics in Austria was uncharacteristically low at 6 percent (Figure 4.3).

The diffusion of these informational technologies in Europe is more widespread in the services sector than in the manufacturing sector. The share of firms using cloud computing services, for example, is highest in the information and communication services subsector (Figure 4.4). Other segments of the services sector that are relatively more intensive in the use of cloud computing include professional, scientific, and technical services, administrative and support services, real estate, and accommodation.

The use of ML and/or AI software by firms in Europe is on a par with the United States. According to survey data collected by the European Investment Bank, about 25 percent of firms in the United States report having partially or fully adopted cognitive technologies, such as big data analytics and AI, compared with about 20 percent in the EU.<sup>2</sup> This adoption rate is higher, relative to the United States, in the Netherlands, Finland and Denmark where more than one-third of manufacturing and services sector firms used big data analytics and AI in 2019 (Figure 4.5). The corresponding share was about 15 percent in other EU-14 countries such as France, Germany and Italy. Estonia among EU-13 countries, where one-fourth of manufacturing and services sector firms used big data analytics and AI, stands out. Globally, the majority of firms using ML and/or AI software belong to the services sector. And within services, a

**FIGURE 4.3** The share of firms using big data analytics is lower than for cloud computing and business management software across Europe

Share of firms that purchased big data analytics, 2018



Source: Eurostat and OECD.

**FIGURE 4.4** The use of cloud computing in Europe is more widespread in the services sector, especially information and communication services

Share of firms that used cloud computing, by sector, 2018

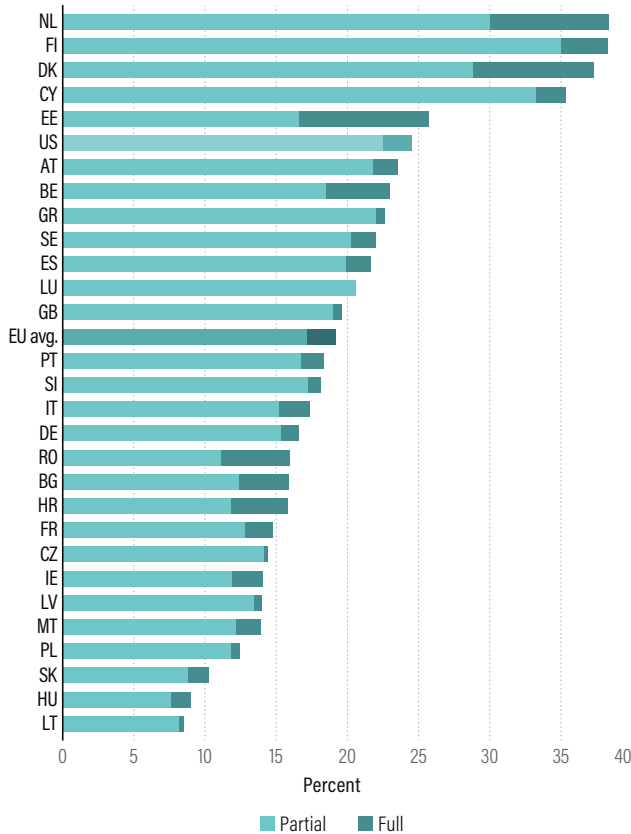


Source: Eurostat.

disproportionately large number of firms are in the computer software and IT industries, followed by higher education, health care and financial services (Figure 4.6).

**FIGURE 4.5** The use of ML and/or AI software by firms in Europe is on a par with the United States

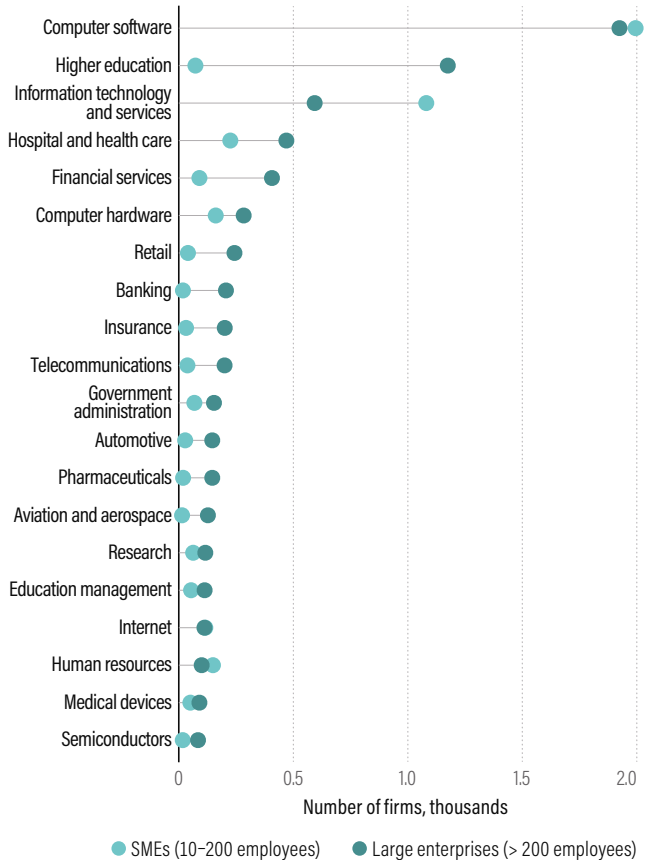
Share of firms that report having partially or fully adopted cognitive technologies such as AI and big data analytics, 2019



Source: EIB-WBG background paper by Cathles, Nayyar, and Rückert (2020).  
 Note: AI = artificial intelligence; ML = machine learning; EU = European Union.

**FIGURE 4.6** The majority of firms using ML/AI software are in the services sector

Number of firms that purchased AI and ML software, by industry, 2018



Source: iDatalabs.  
 Note: AI = artificial intelligence; ML = machine learning; SME = small and medium enterprise.

## Is Europe a global leader in the creation of informational technologies?

The United States is ahead of Europe (except for the United Kingdom) in terms of investment in advanced ICT services, such as cloud computing (Atkinson, 2018). Seventeen of the top 25 cloud computing vendors are headquartered in the United States and earn, on average, twice the revenue of the EU-based applications vendors. The few vendors that are headquartered in Europe are concentrated in just a handful of countries in the EU-14 and the United Kingdom. Of the top-five cloud providers with headquarters in Europe, two are in Germany (SAP and T-Systems), and one each in France (Cegid), the Netherlands (Unit 4), and the United Kingdom (SmartFocus). Furthermore, European IT firms are often the target of U.S. acquisitions, and rarely do European firms acquire U.S.-based IT firms, leading to a relatively small presence of domestically owned IT firms in Europe (European Commission, 2016).

The AI and ML landscape is relatively evenly divided between the United States, Europe (taken as a whole), China and the rest of the world. In 2016, AI companies were concentrated in the United States (2,095 companies),

China (709 companies) and Europe (662 companies: 366 in the United Kingdom, 160 in Germany and 136 in France). Of a broader set of 16,000 players involved in AI research and innovation between 2009 and 2018, the EU accounted for 25 percent, just behind the United States (28 percent) and just ahead of China (23 percent) (Craglia et al., 2018).<sup>3</sup> While Europe (taken as a whole) is comparable to China and the United States, no single country within Europe has close to the number of AI players as China or the United States. Bulgaria, Cyprus, Estonia and Malta have large numbers of AI players relative to the size<sup>4</sup> of their economies. The same holds true for Israel and Singapore (Craglia et al., 2018).

The major AI players in Europe are evenly divided between research and industry, while those in the United States and China, respectively, are concentrated in industry and research. Forty-five percent of the AI start-ups are in the United States, followed by 27 percent in the EU. Similarly, more than one-third (37 percent) of the AI venture capital flows are directed to start-ups in the United States, followed by 27 percent to the EU (Craglia et al., 2018). The United States and the EU also dominate frontier research, each accounting for one-third of papers submitted to top AI conferences (Craglia et al., 2018). At the same time, China claims an overwhelming 57 percent of AI patent applications, while the United States (13 percent), the Republic of Korea (7 percent) and the EU (7 percent) trail China's patent applications by a considerable distance (Craglia et al., 2018).

Digital platforms and tech companies that have pioneered the use of these informational technologies are almost all headquartered outside Europe. Microsoft Azure, for example, provides data centers and cloud services. Other tech companies headquartered in the United States, such as Apple, Alphabet/Google, and Facebook, generate well over US\$1 million in revenues per employee per year, which exceeds the corresponding ratio for many traditional industrial companies by a factor of four to ten. SAP is the only global leader in the space of information technologies that is headquartered in Europe. The operating margins of these large technology companies are also comparatively high (Fraunhofer, 2019). Value added per worker and profit margins in these platform companies are typically larger because they primarily sell intangible goods and services (advertising space, software, etc.), and can be easily scaled up owing to the low marginal costs of supplying additional consumers.

## INFORMATIONAL TECHNOLOGIES AND EUROPE'S ECONOMIC COMPETITIVENESS

### Is the use of informational technologies associated with higher levels of productivity in Europe?

There is a body of evidence documenting the contribution of traditional ICT to productivity improvements in Europe. Atkinson (2018) summarizes a slew of papers in the late 1990s and early 2000s that demonstrates the positive effect of ICT on productivity in Europe. These papers include: (i) firm-level studies in France, Germany and the United Kingdom that find a positive effect of internet-integrated business systems on productivity levels; (ii) firm-level studies in Italy that establish a positive relationship between ICT investment and efficiency; and (iii) sector-level studies in the United Kingdom that show that the industries investing the most in ICT in the first decade of the 2000s contributed the most value added to growth in the country. Based on firm-level data from 14 European countries from 2002 to 2010, UNCTAD (2015) finds that firms that reported a greater presence of broadband systematically had higher levels of labor productivity than less well-connected firms.

Using the Organisation for Economic Co-operation and Development's (OECD) data from 1985 to 2016, Atkinson (2018) shows that almost 30 percent of productivity growth that occurred in the United States between 2013 and 2015 can be attributed to ICT capital, compared with between 7 and 23 percent in European countries.

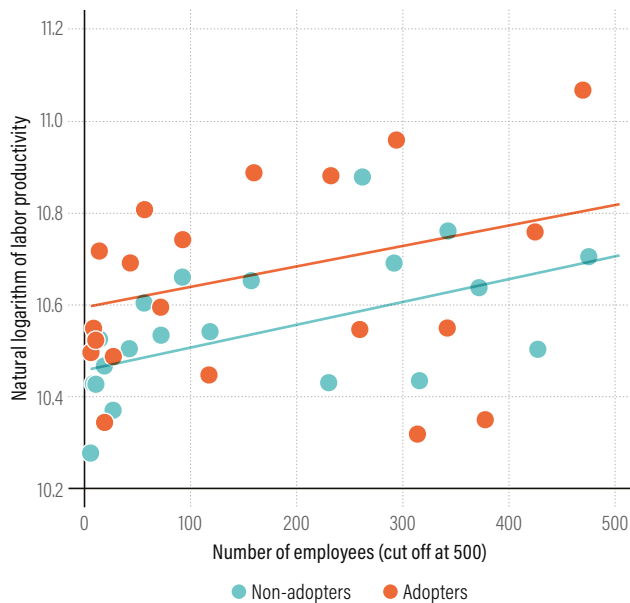
The author also shows that there are only two countries in Europe (Denmark and Sweden) where ICT capital contributed more to the country's gross domestic product (GDP) growth rate than it did in the United States.

The use of advanced ICT services has also contributed to productivity improvements in Europe. Based on data from 20 European countries<sup>5</sup> and 22 industries between 2010 and 2015, Gal et al. (2019) find that greater adoption of ERP software, CRM software, and cloud computing in an industry is associated with higher multifactor productivity growth for the average firm.<sup>6</sup> The European Commission (2016) estimates that cloud computing could lead to the creation of around 300,000 new businesses from 2015 to 2020. For a sample of retailers in the United Kingdom between 2009 and 2015, Sena and Ozdemir (2019) find that efficiency is positively related (with a lag) to investment in big data analytics.<sup>7</sup>

These informational technologies improve productivity by enabling data-driven decision-making. Using data from a survey of 179 publicly traded firms in the United States about their business practices, information systems, and the use of information and publicly available financial data from 2005 to 2009, Brynjolfsson et al. (2011) find that, on average, a one-standard-deviation increase in data-driven decision-making is associated with being 4.6 percent more productive. The literature identifies access to information external to the firm, and potential complementarities between organizational structure and IT investment, as potential mechanisms through which IT can influence productivity (Brynjolfsson et al., 2011).

**FIGURE 4.7** For a given firm size category, firms that adopted AI and big data analytics are more productive than firms that did not

Labor productivity by firm size (number of employees) and adoption of AI and big data, 2019



Source: EIB-WBG background paper by Cathles, Nayyar, and Rückert (2020).

Note: Firms are weighted with value added. This bins scatter plot groups the number of employees into equal-sized bins (default = 20), and then computes the means for firm size and log labor productivity within each bin.

As an application of AI, ML elevates the role of data in improving productivity growth. Cockburn et al. (2018) emphasize the deep learning aspect of AI that generates the possibility of creating new ways to invent things. In a modeling exercise, Aghion et al. (2018) show that the outlook for growth looks good when AI/ML contributes to the production of ideas, and that countries closer to the technological frontier may face fewer obstacles in acquiring the kind of machinery capable of idea production.

The systematic documentation of how ML affects productivity is missing because: (i) the technology is still nascent and in the process of diffusing; and (ii) the value creation of intangible capital is not fully captured in traditional metrics (Brynjolfsson et al., 2017). Recent EIB survey data across the EU-28 and the United States indicate that the partial or full implementation of big data analytics and AI is positively related to firm-level labor productivity (Annex Table A4.1).<sup>8</sup> In fact, for a given firm size category, technology adopters are more productive than non-adopters (Figure 4.7). Examples also abound. Google's DeepMind team has used ML systems to improve the cooling efficiency at data centers by more than 15 percent. Amazon employs ML to optimize inventory and improve product recommendations to customers (Brynjolfsson and McAfee, 2017). The use of vast amounts of data from CVs and social media profiles has improved the productivity of firms such as Gild and Entelo in their recruiting tasks (Schulte, 2019).

## Is the use of informational technologies associated with reshoring to or less offshoring from Europe?

The ICT revolution made it feasible to exploit the potential benefits of international production fragmentation, enabling the remote coordination of complex tasks at relatively low cost (Batra and Casas, 1973; Dixit and Grossman, 1982; Jones and Kierzkowski, 1990, 2001). Freund and Weinhold (2004) suggest that a 10-percentage-point increase in growth of web hosts for the average country in the sample contributed to about a 1-percentage-point increase in annual exports growth. Similarly, Osnago and Tan (2016) find that a 10 percent increase in an exporter's rate of internet adoption led to a 1.9 percent increase in bilateral exports. Using firm-level census data from the United Kingdom, Abramovsky and Griffith (2005) find that an increase in ICT investment is associated with an increased probability of offshoring. Furthermore, Fort (2017) shows that the adoption of communication technology is associated with a 3.1-percentage-point increase in the probability of production fragmentation based on a sample of U.S. firms.

Newer informational technologies can further reduce coordination costs by making it easier to track and monitor components as they move through the supply chain. Cloud computing, for example, can change the landscape of information storage and exchange, and enable better, more cost-effective coordination of globally fragmented production. Of late, the analysis of large, fast-moving, and varied streams of 'big data' has received much attention, since it can enable firms in GVCs to optimize complex distribution, logistics and production networks. A 2011 Microsoft survey of 152 decision-makers within automotive, aerospace, electronics and industrial equipment manufacturing companies in France, Germany and the United States found that customer transaction data can enable firms to better forecast demand, thereby reducing inventory costs by 20 to 30 percent (Microsoft Corporation, 2011).

ML can also boost international trade by reducing language barriers, which is especially relevant for countries in Europe. Comparing whether exports from the United States to countries where eBay implemented its machine translation system<sup>9</sup> changed vis-à-vis countries where it did not, Brynjolfsson et al. (2018) find that U.S. exports to Spanish-speaking Latin American countries increased by 17.5 to 20.9 percent on eBay.<sup>10</sup> Similarly, the introduction of eBay Machine Translation (eMT) was associated with an increase in exports from the United Kingdom to France, Italy and Spain by around 13 percent.<sup>11</sup> This suggests that buyers with higher translation-related search costs experience greater benefit from eMT and therefore a larger increase in trade. Moreover, Brynjolfsson et al. (2018) reflect that the magnitude of the effect of eMT on exports is greater than an estimated reduction in physical distance between countries, suggesting that the capability of ML to cut language barrier friction is of first-order importance in increasing connectivity.

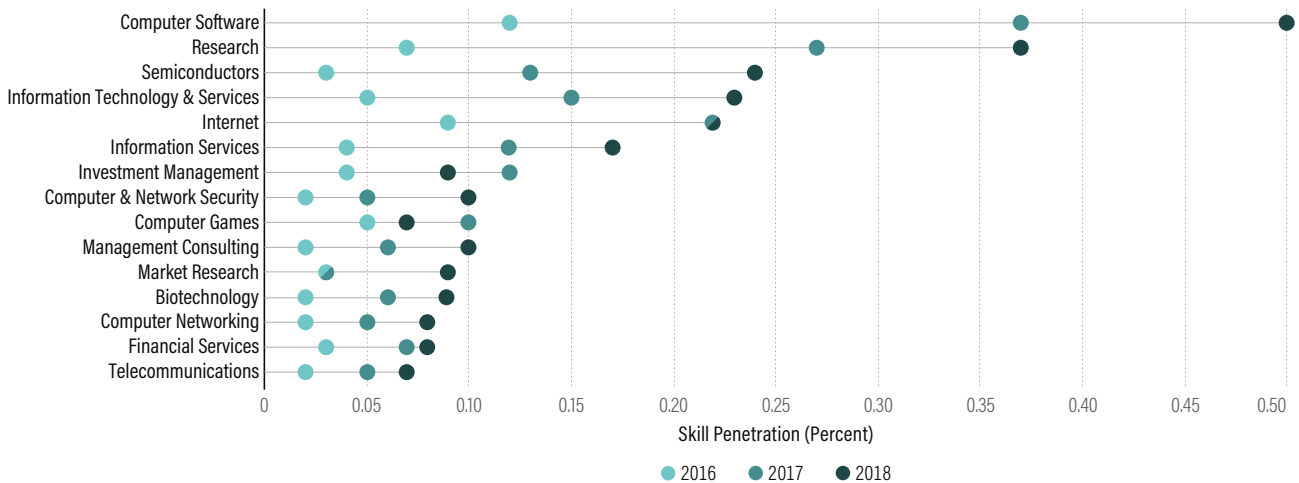
ML algorithms, at the same time, could result in the reshoring of IT-enabled professional services, such as call centers, to high-wage countries. Transcripts from online chats between salespeople and customers can be used as training data for a chatbot to recognize those answers to common queries that are most likely to lead to sales (Brynjolfsson and McAfee, 2017). Combined with voice recognition ML software, this can potentially reshore call center services and other business process outsourcing to advanced economies. The penetration of AI skills in advanced countries is indeed most widespread in the computer software and IT services industries, and has increased significantly between 2016 and 2018 (Figure 4.8). Furthermore, data from online recruitment portal Jobstreet show that available business process outsourcing jobs for fresh graduates in the Philippines declined by one-third between 2016 and 2017, with AI seen as a contributing factor (Muñiz, 2018).

While there is a paucity of evidence to confirm this, the use of business management software may also result in such reshoring. The Institute for Robotic Process Automation estimates that a 'software' robot costs one-fifth of local workers, and one-third of offshore back-office workers located in, say, India. According to Genfour, which was acquired by Accenture in 2017, while an onshore full-time equivalent worker (FTE) costing US\$50,000 can be replaced by an offshore FTE for US\$20,000, a digital worker can perform the same function for US\$5,000 or less, without the drawbacks of managing and training offshore labor (Baldwin, 2019). Sutherland Global Services, an outsourcing company in Rochester, New York, says it can reduce costs for its clients by between 20 and 40 percent by shifting IT work to a developing economy, but it can reduce costs by up to 70 percent if it couples automation



**FIGURE 4.8** The penetration of AI skills in advanced countries is most widespread in computer software and IT services

Penetration of AI skills, by industry, 2016 - 18



Source: LinkedIn.

software with its U.S.-based employees to complete tasks involving high volumes of structured data (Lewis, 2014). This type of software can therefore reduce the importance of low labor costs in the export of IT-enabled back-office processes. Robotic process automation can also scale up and down rapidly to address, for example, seasonal fluctuations. Software can be used more intensively in busy periods instead of hiring temporary workers (Baldwin, 2019).<sup>12</sup>

## INFORMATIONAL TECHNOLOGIES AND MARKET INCLUSION IN EUROPE

### Is the use of informational technologies biased toward large firms?

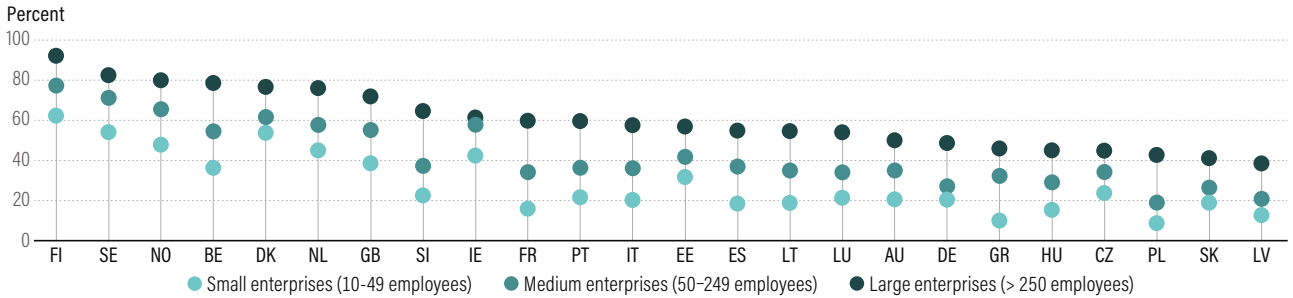
Based on almost 1 million firm-year observations between 2002 and 2013 in Belgium, Dhyne et al. (2018) find that large firms experience higher returns to their investment in IT-related capital investments than small firms do. But there are differences across informational technologies. The gap between the share of large and small firms that use ERP software on average across Europe was 50 percentage points in 2018. In contrast, the gap between the share of large and small firms that use CRM software and cloud computing on average across Europe was 30 percentage points in 2018. Among European countries with the highest share of firms that used cloud computing in 2018, the share of small firms that used the technology was 62 percent in Finland, 54 percent in Sweden and 48 percent in Norway (panel a, Figure 4.9). In contrast, the share of small firms that used ERP software in 2018 was 32 percent in Finland, 26 percent in Sweden and 25 percent in Norway (panel b, Figure 4.9). Furthermore, Gal et al. (2019) find that small firms benefit most from adopting cloud computing and that large firms benefit most from the adoption of ERP software.<sup>13</sup>

The use of cloud computing enables small firms to catch up with large firms. In information and communication services, the subsector in which the use of cloud computing is most widespread, countries with a higher share of firms that adopt this technology have smaller gaps in labor productivity between large and small firms. In sectors that do not use this technology much—such as construction, printing, and fabricated metal products—we do not see this association (Figure 4.10). Cloud computing disproportionately benefits small firms

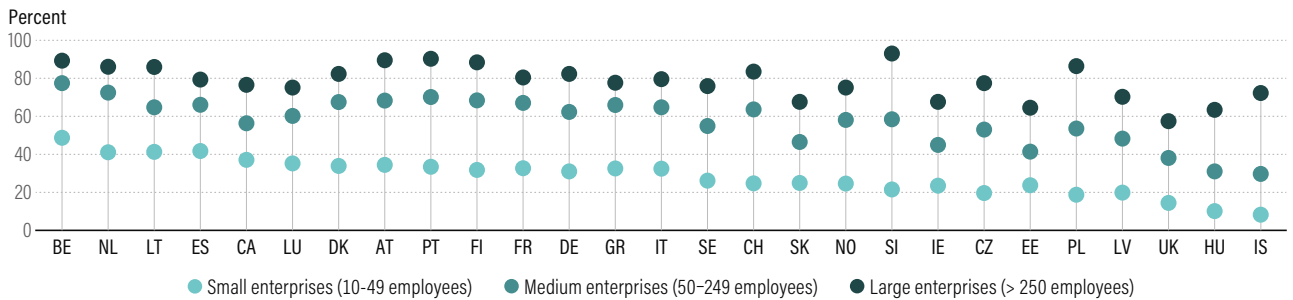


**FIGURE 4.9** The adoption of informational technologies is uniformly more widespread for large firms, although scale matters more for ERP software than cloud computing

a. Share of firms that used cloud computing by firm size, 2018



b. Share of firms that used ERP software by firm size, 2018

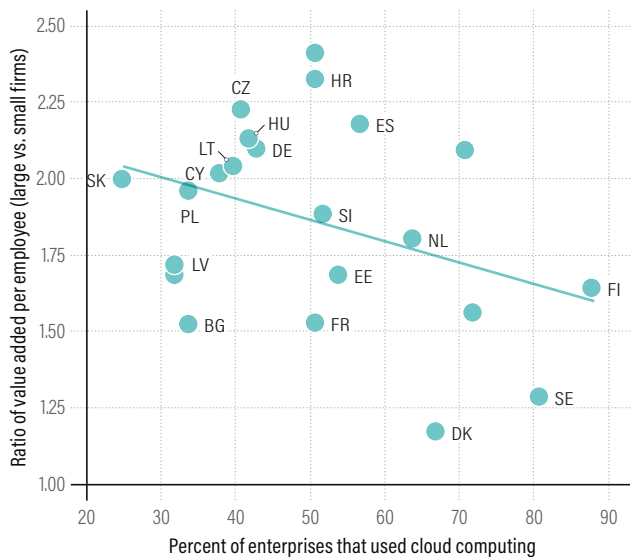


Source: Authors' calculations based on Eurostat.  
Note: ERP = enterprise resource planning.

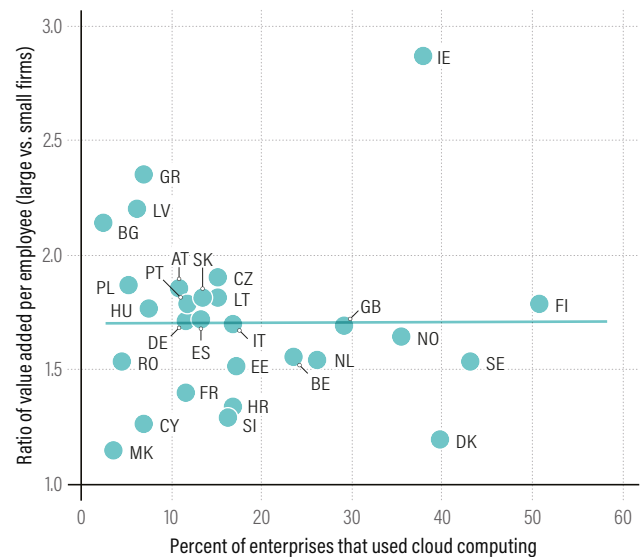
**FIGURE 4.10** The use of cloud computing enables small firms to catch up with large firms

Share of firms that used cloud computing and value added per worker, 2016

a. The use of cloud computing is associated with a smaller productivity gap between large and small firms in information and communication services where this technology is most widespread



b. There is no association between the use of cloud computing and the productivity gap between large and small firms in construction, printing, and fabricated metals, where this technology is least widespread



Source: Authors' calculation based on Eurostat.

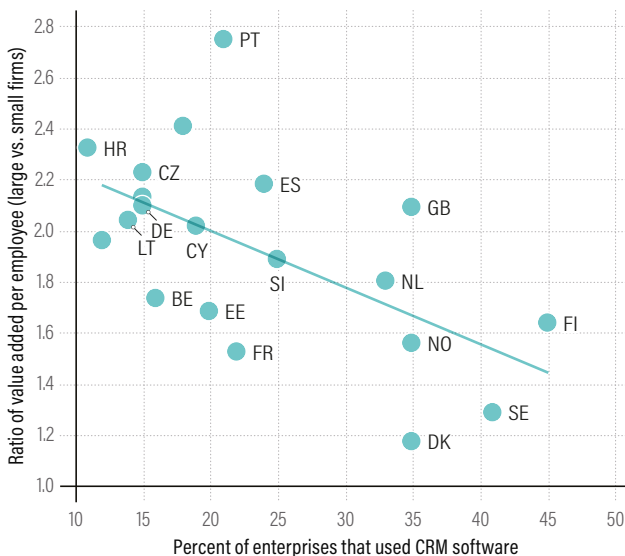
by eliminating upfront capital expenditures associated with information storage and exchange. Cloud services reduce hardware needs for file storage, data backup and software programs. In addition, cloud applications are remotely set up and updated by the vendor, which renders in-person installation and maintenance of hardware and software redundant. Based on data from the United Kingdom, DeStefano et al. (2019) find that cloud computing was associated with a 13 percent annual increase in employment in young firms between 2008 and 2015.

The use of CRM software also allows small firms to catch up with large firms. In information and communication services—the subsector where the use of CRM software is most widespread—countries with a higher share of firms that adopt this technology are also characterized by a smaller gap in labor productivity between large and small firms. For example, labor productivity in large firms is more than double that of small firms in Bosnia and Herzegovina where the share of firms that use CRM software is around 10 percent. In contrast, labor productivity in large and small firms is about the same in Sweden where the corresponding share was more than 40 percent. However, there is no such association, on average, in sectors that use this technology the least—construction, printing, and fabricated metal products (Figure 4.11). This result is consistent with the fact that, unlike physical capital or hardware, the fixed cost associated with installing new software is low. The lack of significant economies of scale in the use of business management software may therefore disproportionately benefit small firms.

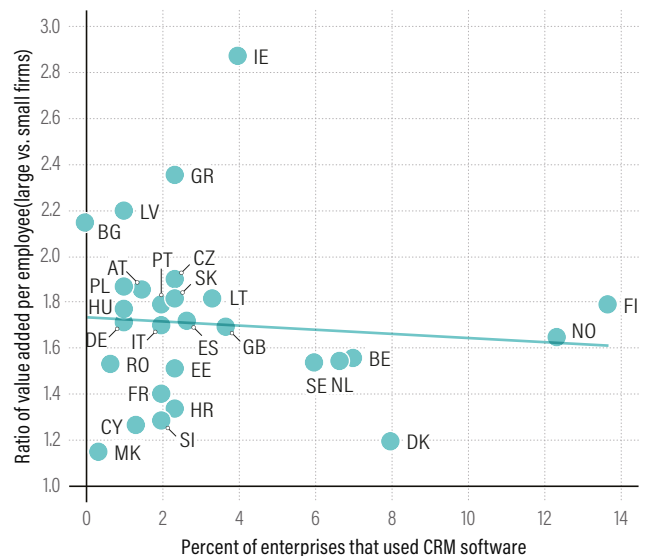
**FIGURE 4.11** The use of CRM software also enables small firms to catch up with large firms

Share of firms that used CRM and value added per worker, 2016 (%)

a. The use of CRM software is associated with a smaller productivity gap between large and small firms in information and communication services where this technology is most widespread



b. There is no association between the use of CRM software and the productivity gap between large and small firms in construction, printing, and fabricated metals, where this technology is least widespread



Source: Authors' calculations based on Eurostat.

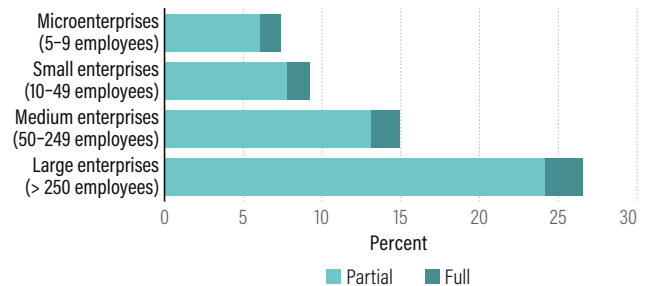
Goldfarb and Trefler (2018) argue that economies of scale in data use to identify statistical regularities lead ML technology to be concentrated in a small number of very large firms. The infrastructure necessary to gather and extract value from data presents a massive barrier to SMEs trying to enter the data race (Li et al., 2019). Among EU countries in 2019, more than 25 percent of large firms in the manufacturing and services sectors used big data analytics and AI, compared with 15 percent among medium-sized firms and less than 10 percent among micro and small firms (Figure 4.12).

Strong network effects, access to data, and zero additional costs of servicing an additional consumer, make ML and big data analytics particularly beneficial for large platform companies. Take, for example, operating systems for mobile

devices—Apple’s iOS versus Google’s Android. Network effects make it less desirable for users to switch to another platform once they have invested in a preferred or favorite platform. Similarly, massive amounts of accumulated user data can enable platform companies to steer users to their own advantage via filtering, framing, ordering results, advertisements, nudging, and so on (Stigler Committee on Digital Platforms, 2019).

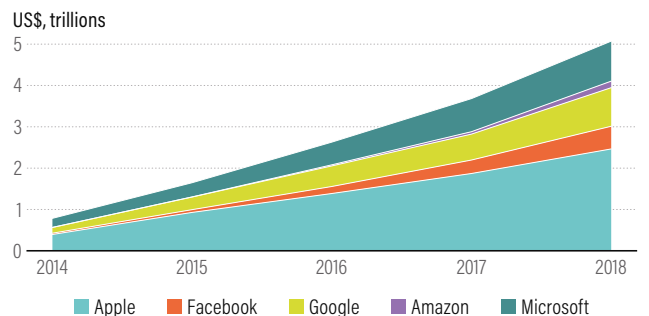
This dominant position of platform firms is reflected in their market capitalization, cash reserves and acquisitions. The combined market capitalization of the five largest platform companies in the S&P 500 Index (Alphabet [Google], Amazon, Apple, Facebook, and Microsoft) amounted to about US\$4 trillion in 2018 (Figure 4.13), which is larger than the sum of the market capitalizations of the 250 smallest companies in the same index.<sup>14</sup> These five companies generated around US\$0.5 trillion in net income (after taxes and interest) between 2014 and 2018, which is about as high as the total profit of all 30 German companies of DAX—including global players from multiple industries, such as Allianz, BASF, Bayer, Daimler, SAP, Siemens, and Volkswagen—during the same period. High profits, in turn, have resulted in enormous cash reserves for some of the major platform companies, which are frequently used for acquisitions. Examples include the acquisitions of WhatsApp by Facebook for US\$19 billion, Motorola by Google for US\$12.5 billion, and LinkedIn by Microsoft for US\$26 billion (Fraunhofer, 2019).

**FIGURE 4.12** A notably higher share of large firms relative to SMEs uses big data analytics and AI, 2019



Source: EIB-WBG background paper by Cathles, Nayyar, and Rückert (2020).

**FIGURE 4.13** Cumulative profits of platform companies have been impressive, 2014 – 18



Source: Fraunhofer (2019).

## Is the use of informational technologies associated with fewer jobs?

There is a well-established framework to estimate jobs at risk of automation based on what tasks computers can reliably execute (Autor, Levy and Murnane, 2003). These are procedural, rules-based activities that can be entirely codified as a series of precise instructions, which primarily involve the organization, storage, retrieval and manipulation of information. Such ‘routine’ (or ‘codifiable’) tasks were largely ‘manual’, which is characteristic of many middle-skilled jobs, such as bookkeeping, clerical work and repetitive production. While this framework was developed for ICT, it is equally applicable to other informational technologies.

The diffusion of ICT resulted in labor market polarization in Europe. Goos et al. (2009) find empirical evidence to support a hollowing out of middle-skilled jobs in 16 European counties from 1993 to 2006. The authors explore links with offshoring, but find weak evidence, which they take as support for a technology-based explanation for job polarization in Europe. There is no clear pattern between ICT investment and demand for different skill types, which varied by country and sub-period under consideration (OECD, 2016). However, inequality in Finland, Germany and Sweden increased over the previous two or three decades more than it did in the United States, which Brynjolfsson and McAfee (2014) take as evidence of the exponential change in digital technology, rather than policy, being responsible for increased inequality in many advanced countries.

Labor substitution effects with the adoption of ICT were found in manufacturing, business services, trade, transport and accommodation, but were typically compensated for by increased demand for labor in culture, recreational services and construction. Combining data for 14 countries, including 12 from the EU, between 1995 and 2012, the OECD (2016) finds that ICT investment is associated with a boost in employment from 1995 to 2001, and once again from 2001 to 2007.<sup>15</sup> The OECD (2016) cites a study in Germany where most firms surveyed did not expect digitalization

to reduce jobs, and almost one-quarter expected to hire new people to manage the digital transformation. Similarly, the European Commission (2016) indicates that cloud computing would positively impact employment, presenting a lower bound of 300,000 new jobs and an upper bound of 2.5 million new jobs between 2012 and 2015.

ML is increasingly able to automate routine cognitive tasks that could previously only be done by people. Unlike the last generation of information technology that required humans to codify tasks explicitly, ML is designed to learn the patterns automatically from examples (Brynjolfsson and Mitchell, 2017). Rapid progress in ML over the past six to eight years is due in large part to the sheer volume of training data available, which can help capture highly valuable and previously unnoticed regularities—perhaps impossibly large for a person to examine or comprehend. This is particularly noteworthy because the main effects of pre-ML automation were on a relatively narrow range of routine tasks, but ML systems will increasingly be able to replace cognitive tasks. This perception is reinforced by the deceleration of employment growth in abstract task-intensive occupations after 2000 (Beaudry, Green and Sand, 2016; Mishel, Shierholz and Schmitt, 2013).<sup>16</sup>

The biggest improvement has been in cognition and problem-solving, whereby patterns in the data reveal regularities that humans are unable to either observe or articulate. For instance, creating a new computer program until recently involved a labor-intensive process of manual coding. But this expensive process is increasingly being automated by running an existing ML algorithm on appropriate training data (Brynjolfsson and Mitchell, 2017). Sophisticated ML algorithms function as robo-lawyers (Lex Machina and Ravel Law) that can plough through information and suggest legal strategies (Baldwin, 2019). ML is being used by the cybersecurity company Deep Instinct to detect malware and by PayPal to prevent money laundering. Dozens of companies are using ML to decide which trades to execute on Wall Street.

The second major area of improvement has been in perception-related tasks, particularly through voice and image recognition. Voice recognition is now about three times as fast, on average, as typing on a cell phone and the error rate has dropped from 8.5 to 4.9 percent since the summer of 2016. It is therefore not surprising that millions of people are now using Siri, Alexa and Google virtual assistants. Similarly, the error rate for recognizing images from a large database called ImageNet fell from higher than 30 percent in 2010 to about 4 percent in 2016 for the best systems. Aptonomy and Sanbot, makers of drones and robots, respectively, are using improved vision systems to automate much of the work of security guards. Enlitic is one of several deep-learning start-ups that use image recognition to scan and read medical images to help diagnose cancer (Brynjolfsson and McAfee, 2017).

This progress notwithstanding, labor will remain important in nonroutine tasks that require more effective judgment, creative thinking and personal interaction. First, ML algorithms work well only to the extent that real-world phenomena mirror the distribution of training examples (Brynjolfsson and Mitchell, 2017). Their consistency and accuracy therefore remain a concern, with expectations that they will only ever “get it right” on average, while missing many of the most important and informative exceptions (Autor, 2015). Second, ML systems work well only when solutions can be automatically evaluated as right or wrong, or at least better or worse. For example, whereas computers can diagnose certain types of cancer, as well as, or better than, human doctors, their ability to explain why or how they came up with the diagnosis is relatively poor. Third, ML systems are less effective when the task requires common sense or background knowledge, such as in unstructured personal interaction, which often involves emotional and inconsistent human beings.<sup>17</sup>

There are risks of increased inequality too. Using data from LinkedIn, Brynjolfsson et al. (2019) argue that value creation from ML stems from the IT-related intangible capital and skills that are complementary to ML. Citing Autor and Salomons (2017), Craglia et al. (2018) also argue that AI/ML could perpetuate wage polarization, whereby high-skilled workers and owners of capital reap the rewards. At the same time, even if many human tasks can be replaced with AI, the labor share in value added will remain substantial because the last human tasks will continue to be necessary and will be well compensated.<sup>18</sup> This relates to essential tasks that are hard to automate—those that require effective judgment, creative thinking and personal interaction are a case in point. These can be both at the lower and upper ends of the skills distribution. Furthermore, AI might begin to contribute to new ideas and thus increase productivity, which in turn has the potential to create new tasks and jobs (Aghion et al., 2018).

# INFORMATIONAL TECHNOLOGIES AND GEOGRAPHIC CONVERGENCE IN EUROPE

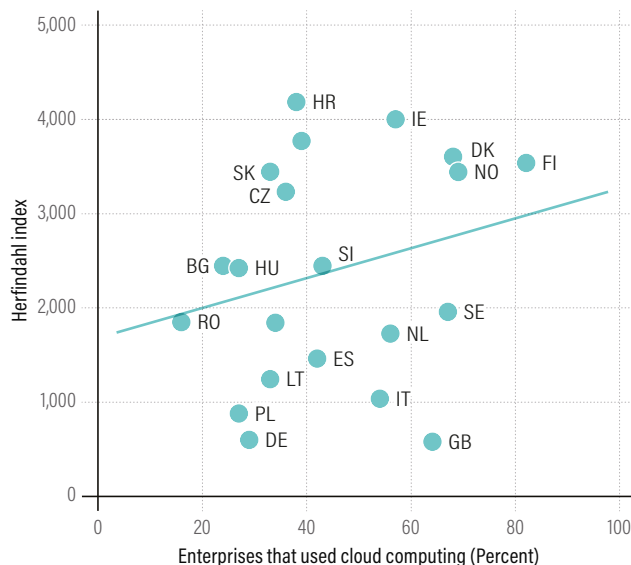
## Is the use of operational technologies associated with a higher spatial concentration economic activity in certain European regions?

In principle, the use of informational technologies should expand opportunities in more locations, because they reduce coordination costs. Analyzing data for 232 European regions at the NUTS2 level in 2007 and 2010, Barbero and Rodriguez-Crespo (2018) find that the spread of broadband internet reduced regional disparities by boosting inter-regional trade. At the same time, Schivardi and Schmitz (2018) show that IT was associated with almost 12 percent of productivity growth in German firms from 1995 to 2008, compared with around 5 percent in Spain and Portugal. The adoption of IT exacerbated existing productivity differences between firms in Germany and these South European economies, because of lower adoption levels and less efficient management practices.<sup>19</sup>

Evidence on the impact of informational technologies beyond ICT on spatial concentration in Europe is similarly mixed. DeStefano et al. (2019) show that cloud computing is associated with greater geographic dispersion for incumbent firms in the United Kingdom.<sup>20</sup> The authors also show that the greater geographic dispersion for incumbent firms is the result of employment shifts, rather than the opening (or closing) of plants. However, the use of cloud computing is not negatively associated with lower spatial concentration of economic activity across European countries in the ICT services subsector, where this technology is most widespread (panel a, Figure 4.14). For example, the shares of firms that use CRM software in Slovakia and Finland are notably different, at less than 10 percent and more than 40 percent, respectively, but the Herfindahl Index of Concentration based on the number of firms at the NUTS2 level is similar. However, the use of CRM software is similarly not associated with geographical dispersion (panel b, Figure 4.14).

**FIGURE 4.14** The use of cloud computing has not resulted in geographic convergence in Europe

a. Share of firms that use cloud computing and the Herfindahl Index of Concentration in information and communication services based on the number of firms at the NUTS2 level, 2016



b. Share of firms that use CRM software and the Herfindahl Index of Concentration in information and communication services based on the number of firms at the NUTS2 level, 2016



Source: Authors' calculations based on Eurostat.

Note: NUTS = Nomenclature of Territorial Units for Statistics.

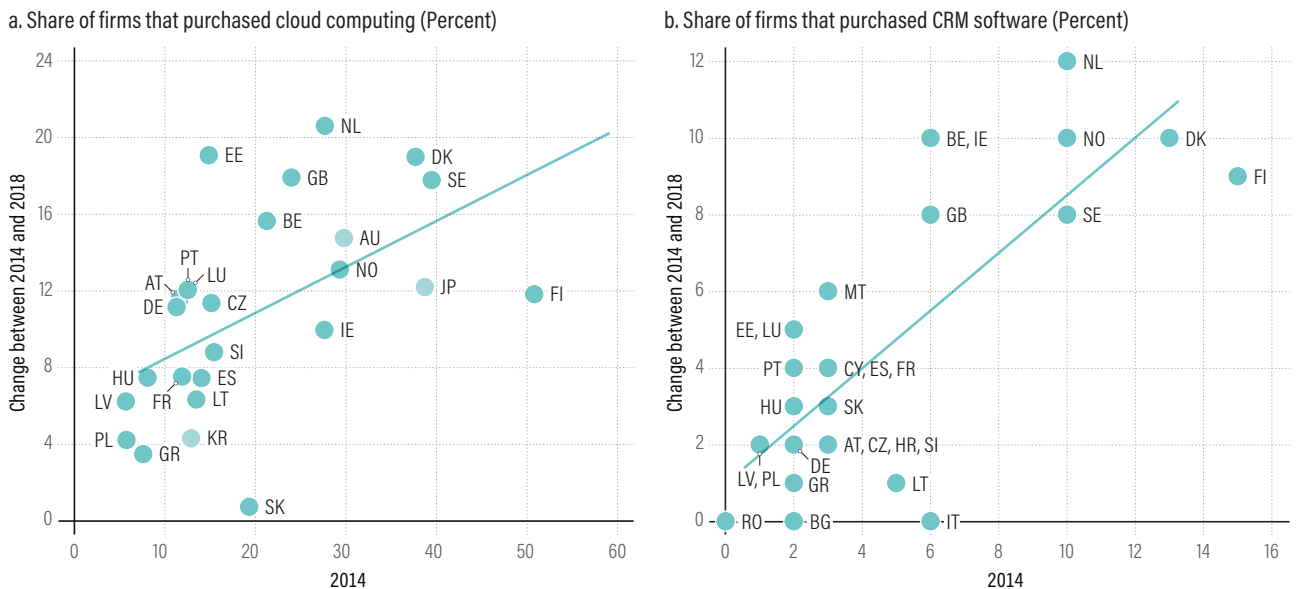
The use of informational technologies can lead economic activity to locate in regions with better broadband access. Andrews et al. (2018) use data from 25 industries in 25 European countries between 2010 and 2016 to show that the presence of high-speed broadband is crucial for the adoption of advanced digital technologies, such as cloud computing and ERP and CRM software. Regions without access to high-speed (greater than 30 Mbps) broadband internet are at a disadvantage. Similarly, based on firm-level data by zip code in the United Kingdom, DeStefano et al. (2019) show that access to broadband and its expected speed are significant predictors of the adoption of cloud computing. Based on statistics from Cisco, the authors show that average broadband speed is more than 10 Mbps slower in Central and East Europe (24.8), and about 6 Mbps slower in West Europe (30.2), than in the United States (36.1).

The use of informational technologies can also lead economic activity to locate in regions with a greater availability of skilled labor. For a sample of retailers in the United Kingdom between 2009 and 2015, Sena and Ozdemir (2019) find that the availability of graduates increases the payoff to investment in big data analytics. This suggests that firms may want to locate in areas with a high density of graduates. Based on data from 25 industries in 25 European countries between 2010 and 2016, Andrews et al. (2018) show that if management practices in Greece were at the level they are in Denmark, or if the quality of management schools was equivalent to that in Belgium, the country could expect to see a 10 percent increase in cloud computing in its knowledge-intensive industries. Similarly, Oliveira et al. (2014) find that top management support played a decisive role in the decision to adopt cloud computing in Portugal.

## Is the technology itself concentrated in some European regions?

There is little evidence of catch-up in the share of firms using informational technologies across countries, which suggests that diffusion has been greater within countries. Countries with the highest share of firms that used CRM software and cloud computing services in 2014 also experienced the highest growth rates in this share subsequently between 2014 and 2018.<sup>21</sup> These countries include Denmark, Finland, the Netherlands, Norway and Sweden. In contrast, Greece and Poland had among the smallest shares of firms that used these informational technologies in 2014, but also experienced the lowest growth rates in these shares between 2014 and 2018 (Figure 4.15). For example, in 2014, Sweden had one of the highest shares of firms that used cloud computing, at 40 percent,

**FIGURE 4.15** There is little evidence of catch-up in the share of firms using informational technologies across countries



Source: Authors' calculations, based on Eurostat.  
 Note: CRM = customer relationship management.



and Poland among the lowest, at around 5 percent. Nonetheless, Sweden also experienced an 18 percent increase in this share between 2014 and 2018, while Poland experienced only a 4 percent increase. These patterns are indicative of divergence in the diffusion of informational technologies between leading and lagging countries.

The top regions with respect to their potential future participation in the development of cloud computing, as measured by patents, are spread evenly across Europe.<sup>22</sup> Together, France, Germany and the United Kingdom constitute more than half of all top 20 EU regions with regard to their potential future participation in the development of all Industry 4.0 technologies. Although the United Kingdom comprises three of the top five regions, the distribution is much more even in the case of cloud computing. Together, France, Germany and the United Kingdom constitute less than one-third of all top 20 EU regions. The others are spread across member countries of the EU-14—Austria, Finland, Germany, Ireland, the Netherlands, Sweden—and Switzerland. Regions from the EU-13 in the Czech Republic, Hungary and Poland also find a place in the top 20 (Boschma and Balland, 2019).

The United Kingdom dominates the AI landscape within Europe with around 25 percent of all AI players in the erstwhile EU-28 and about half of the top 20 EU regions with respect to their potential for developing AI patents particularly stands out. Other frontrunners include countries in the EU-14. Germany and France, respectively, account for 15 and 11 percent of the AI players in the erstwhile EU-28. Italy, the Netherlands, Spain and Sweden are the next in line in terms of the number of AI players by country as a percentage of the world total (Craglia et al., 2018).

Furthermore, there is a clustering of regions with respect to their potential future participation in the development of AI and ML in capital city regions or commercial hubs across Europe, such as London, Île-de-France, Comunidad de Madrid, Berlin, Vienna and Helsinki (Boschma and Balland, 2019). London, Berlin and Paris are also leading spots in the region in terms of AI venture capital, AI skills and leading research in the field (Simon, 2019). These cities have emerged alongside Boston, Seattle, Shanghai, Silicon Valley, and to some extent Montreal and Toronto, as cities with global expertise in AI (Goldfarb and Treffer, 2018). This clustering of AI and ML is consistent with findings that more complex technologies disproportionately concentrate in large cities (Balland and Rigby, 2017; Balland et al., 2018). AI companies tend to locate where their intellectual inventors are living (e.g., Google Deepmind and Uber's AI office), and thus have close ties to universities.

## CONCLUSION

The share of firms using ERP and CRM software, cloud computing and big data analytics is far from universal, but notably higher among member countries of the EU-14. Outside of the EU-14, Estonia and Lithuania belonging to the EU-13 North group had the highest adoption rates for these informational technologies. There is a difference in penetration rates across these informational technologies too. Across European countries, on average, the share of firms using cloud computing is higher than the share using ERP and CRM software which, in turn, is higher than the share of firms using big data analytics.

The AI and ML landscape is relatively evenly divided between China, Europe and the United States. The major AI players in Europe are evenly divided between research and industry, while those in the United States and China, respectively, are concentrated in industry and research. Forty-five percent of the AI start-ups are in the United States, followed by the 27 percent in the EU. The United States and the EU also dominate frontier research, each accounting for about one-third of papers submitted to top AI conferences, while China claims an overwhelming share of AI patent applications. The AI landscape within Europe is dominated by the United Kingdom and some EU-14 countries.

The contribution of business management software, cloud computing and big data analytics to productivity improvements in Europe is well-documented, but there is a paucity of empirical evidence on the economic



effects of existing forms of ML. The evidence on whether these informational technologies have resulted in reshoring or strengthen offshoring is inconclusive. Big data and cloud computing can strengthen offshoring by reducing coordination costs. At the same time, the use of business management software might result in the reshoring of back-office services to high-wage countries, and the IoT may make it more efficient to rebundle activities in ‘smart’ factories. Machine translation can boost international trade by reducing language barriers on the one hand, but ML-enabled voice recognition can reshore call-center services to high-wage countries on the other hand.

The use of cloud computing and business management software reduces the performance gap between large and small firms. This is not surprising given cloud computing services, for example, can allow access to sophisticated technological services without building in-house capabilities. At the same time, big data analytics and ML algorithms require large amounts of data to identify empirical regularities and are therefore likely to benefit large firms. This is particularly true of large platform tech companies—the market capitalization of the two largest ones exceeds that of all 30 German companies of DAX, combined.

The spread of computers and the internet increased aggregate employment in Europe but resulted in labor market polarization by automating middle-skilled jobs comprising routine tasks. ML is increasingly able to automate routine cognitive tasks, based on hitherto unobserved regularities in the data. Even as job functions become automated, the demand for labor will continue to grow in nonroutine tasks that require more effective judgment, creative thinking and personal interaction. There are risks of increased inequality, if ML disproportionately benefits owners of capital and highly skilled labor remains least susceptible to automation.

There is little evidence of catch-up in the share of firms using business management software and cloud computing across countries in Europe. With broadband access and the greater availability of skilled labor being important pre-requisites, it is therefore not surprising that the use of these informational technologies has not resulted in greater geographic convergence in Europe. There is also a clustering of regions with respect to the development of AI and ML technologies. The United Kingdom, Germany and France account for half of all AI players in the EU. And within countries, the potential for developing AI capabilities is highest in capital city regions.

## Notes

1. The share of firms using ERP software was uncharacteristically low in the United Kingdom at 19 percent and the share of firms using CRM software in Germany was uncharacteristically low at 4 percent.
2. Firms classified in manufacturing (NACE C), services (NACE G/I), or infrastructure (NACE D/E/H/J) were asked about the use of cognitive technologies, while those classified in Construction (NACE F) were not.
3. The methodology involves the creation of a comprehensive dictionary of keywords and then using those keywords as search terms in business registries, analysis of R&D activities, patents, conference proceedings and research, to identify the main players in AI.
4. Number of AI players weighted by GDP.
5. Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, the Netherlands, Poland, Portugal, Slovenia, Spain, Sweden, Turkey, and the United Kingdom.
6. The authors argue that combining industry level adoption rates with firm level productivity data helps skirt some endogeneity issues that could otherwise plague the analysis.
7. The authors use investment in computer software and databases as a proxy for big data analytics.
8. This controls for country- and industry-specific factors.
9. eBay Machine Translation (eMT) is an in-house ML system that statistically learns how to translate different languages. The eMT makes it easier for shoppers from other countries who speak another language to search for products, reducing their personal “cost” of translating.
10. Using a number of language pairs, the authors employ a difference-in-difference analysis to explore the effects on exports from the United States to other countries after the eMT technology was adopted.
11. In order to promote intra-EU trade, U.S. eBay pages were not translated.
12. In addition, the work is more consistent and leaves a digital trail that makes reporting for regulatory compliance reasons faster and reliable.
13. Drawing on data from more than 1 million firms in the United States about their use of hardware and software since the 1980s, Bloom and Pierrri (2018) find that micro firms (less than 10 employees) and the youngest firms (less than four years old) have the highest cloud computing adoption rates.

14. Such a concentration is not unusual historically. For example, AT&T Inc. and General Motors Co. represented about 14.5 percent of the S&P 500 in 1965. Interestingly, AT&T as a telecommunication company also benefited from network effects.
15. This includes Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain and Sweden. However, this pattern is almost completely reversed in Ireland.
16. Evidence suggests that ML is more likely to automate certain tasks within an occupation, which is likely to spur the reshuffling of tasks rather than directly substituting for particular jobs (Brynjolfsson et al., 2019). This is based on a rubric that classifies nearly 20,000 tasks in 950 occupations based on occupational data from O\*NET in the United States.
17. ML has begun to make inroads here too. For example, the software company Affectiva is using image and voice recognition to discern emotions such as joy, surprise, and anger in focus groups.
18. Aghion et al. (2018) find that it is possible, under reasonable assumptions in future AI growth scenarios, for a relatively high capital share to remain constant (never reaching 100 percent) and balanced (low aggregate) growth to occur.
19. The combined effect of lower levels of IT diffusion and inferior management practices in firms may have led to dampened domestic demand for high-skilled workers, prompting those workers to immigrate to seek employment in other countries with a richer set of employment opportunities, spurring further divergence in the Southern European economies (Schivardi and Schmitz 2018).
20. The average employee works in plants that are around 24 km further away from headquarters.
21. These data are not available in a long time series.
22. The ability of regions to develop new technologies depends on capabilities related to their existing technological specializations. Countries and regions are more likely to develop new activities related to their existing activities. This principle of relatedness can be used to identify the potential of regions to develop operational technologies (Boschma, 2017; Hidalgo et al., 2018).

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# ANNEX 4

**TABLE A4.1** Relationship between AI/big data analytics and labor productivity, firm level, 2019

		AI and big data analytics
Digital technology		0.09* (0.05)
Sector	Manufacturing	Reference Sector
	Construction	N/A
	Services	-0.33*** (0.04)
	Infrastructure	0.02 (0.04)
Adjusted R-Squared		0.17
N		8084

Source: Cathles, Nayyar and Rückert (2020), using data from the 2019 EIBIS Survey.

Note: The dependent variable is log of labor productivity. The constant and country dummies are included, but not reported. Firms in different sectors were asked about different digital technologies, N/A indicates when a sector was not asked about a particular technology. The reference sector is also indicated. Firms in EIBIS are weighted with value added. All countries in the EU-28 and the United States are included in the regressions. Robust standard errors in parentheses. AI = artificial intelligence.

\* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

**TABLE A4.2** Relationship between AI/big data analytics and employment growth, firm level, 2019

Digital adoption	0.31*** (-0.12)	0.15 (-0.13)	0.27* (-0.15)
Manufacturing	Reference	Reference	Reference
Construction			
Services	-0.24** (-0.11)	0.03 (-0.12)	0.19 (-0.14)
Infrastructure	-0.07 (-0.1)	0.15 (-0.12)	0.12 (-0.13)
Micro	Reference	Reference	Reference
Small		0.78*** (-0.1)	0.79*** (-0.12)
Medium		1.04*** (-0.11)	0.97*** (-0.13)
Large		1.11*** (-0.12)	1.02*** (-0.15)
Less than 5 years	Reference	Reference	Reference
5 years to less than 10 years		-0.16 (-0.31)	-0.49 (-0.32)
10 years to less than 20 years		0.01 (-0.28)	-0.08 (-0.28)
20 years or more		-0.4 (-0.27)	-0.54** (-0.26)

Exporter		0.26** (-0.1)	0.30** (-0.12)
Innovator		0.36*** (-0.1)	
Basic			Reference
Adopting			0.23 (-0.2)
Incremental innovators			0.52*** (-0.15)
Leading innovators			0.32* (-0.19)
Developers			0.35** (-0.14)
N	9702	9400	7121
Pseudo r-squared	0.01	0.04	0.03

Source: Cathles, Nayyar and Rückert (2020), using data from the 2019 EIBIS Survey.

Note: The dependent variable logit is increase in employment compared to 3 years ago = 1, and otherwise = 0. The constant and country dummies are included, but not reported. Firms in different sectors were asked about different digital technologies, N/A indicates when a sector was not asked about a particular technology. The reference sector is also indicated. Firms in EIBIS are weighted with value added. All countries in the EU-28 and the United States are included in the regressions. Robust standard errors in parentheses. AI = artificial intelligence.

\* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .



## CHAPTER 5

# OPERATIONAL TECHNOLOGIES

## INTRODUCTION

New technologies have made it feasible for machines to replace labor throughout history, from the advent of mechanization in agriculture to the more recent spread of information and communication technology (ICT). There is a well-established framework to estimate jobs at risk of automation based on those tasks that computers can execute reliably (Autor, Levy and Murnane, 2003). These are typically routine activities that can be entirely codified as a series of precise instructions to be executed by a computer. While this framework was developed for ICT, it is equally applicable to industrial robots that have the mobility, dexterity, flexibility and adaptability to replace labor on assembly lines.

‘Operational’ technologies associated with Industry 4.0 combine data with automation to reduce the importance of labor costs in routine functions. The focus here is on robotics [particularly artificial intelligence (AI)-enabled], 3D printing and the Internet of Things (IoT), which are among the most emphasized technologies in the Industry 4.0 literature (Cirera, Cruz, Beisswenger and Schueler, 2017). Not all of these technologies are new, but cost innovation, software advances, evolving business formats and changing consumer preferences are fueling their adoption (Comin and Ferrer, 2013). This means that cheap labor as a source of competitive advantage is increasingly giving way to more demanding ecosystem requirements in terms of skills, infrastructure and regulations.

The use of industrial automation to reduce labor costs is becoming increasingly autonomous with the ability to learn from interactions with humans, greatly expanding their range of potential applications over traditional robots. One autonomous robot can possibly fulfill the function of several traditional robots and can be reprogrammed for another task altogether if the need arises (UNIDO, 2016; Manyika, 2013).<sup>1</sup> Similarly, the IoT comprises sensors built into physical objects that enable those objects to be tracked, coordinated, or controlled across a data network in ‘smart’ factories without human involvement (Manyika et al., 2013; UNIDO, 2016).

3D printing technology enables an additive manufacturing process, which builds objects layer by layer, rather than through molding or subtractive techniques, and this enables firms to meet demand for customization more easily. Although 3D printing has mainly been used for prototyping<sup>2</sup> so far, it is likely to play a larger role in the near future with additional advances in materials, speed and reliability (OECD STI, 2016). In fact, it already has a considerable presence or significant potential in certain industries, such as dental implants, hearing aids, prosthetic



limbs and running shoes. These markets are characterized by small batch production, complex products, and demand for customization (Weller et al., 2015). The annual growth rate of 3D printed goods is estimated at 20 percent, with additions to global GDP of US\$0.23 to US\$0.55 trillion per year by 2025 (UNIDO, 2016; Manyika, 2013).

Advanced robotics, the IoT and 3D printing are making labor a smaller share of overall costs. These labor-saving technologies can therefore boost productivity in high-wage economies across Europe and affect traditional patterns of comparative advantage by changing the relative efficiency of firms in high- and low-wage countries. With more established processes, skills, infrastructure, backbone services and networks to use currently accessible technologies owing to a stronger industrial base, it will likely be less challenging for firms in Europe to start adopting these operational technologies as they diffuse (Hallward-Driemeier and Nayyar, 2017).

These operational technologies, by definition, displace labor in certain tasks, but the effect of automation on firms' demand for labor extends beyond the displacement of labor in a given task. Even once the technology is adopted, it might increase the demand for labor in complementary tasks resulting from the productivity gains. An even more powerful countervailing force against automation is the creation of new labor-intensive tasks. In all, such job creation associated with automation might, in principle, outweigh the direct labor displacement effect (Acemoglu and Restrepo, 2018).

The economies of scale, or lack thereof, associated with operational technologies will determine the extent to which they concentrate economic activity in certain firms and regions. Industrial robots, similar to other machinery, typically require substantial capital investment and therefore favor large firms. In ecosystem-intensive industries, such as automotive, electronics, and heavy machinery, which benefit from closely clustered suppliers that can provide inputs on a just-in-time basis, robots also might make it more efficient to re-bundle labor-intensive activities alongside R&D and design-intensive segments in 'smart' factories. This may shorten value chains and concentrate economic activity in certain regions. At the same time, 3D printing may make it feasible to produce in smaller batches, with neither an emphasis on scale nor a larger ecosystem of suppliers — which may be particularly useful for smaller firms and regions with limited industrial bases.

This chapter sheds light on whether and how operational technologies are (re)shaping competitiveness, market inclusion, and geographic convergence in Europe. The analysis to follow focuses on industrial robots and 3D printing, and the industrial IoT as the relevant technology set. This choice reflects their relevance in reducing the importance of labor costs among routine functions in the production process, as well as constraints on data availability. 'Robots', such as drones and self-driving cars, might be just as relevant, but are excluded for these reasons. Competitiveness is measured by productivity, trade and investment patterns. Market inclusion reflects the gap between large and small firms, and between labor and capital. Geographic convergence reflects differences in production outcomes, as well as technology diffusion and creation between European countries and regions at the NUTS2 level.

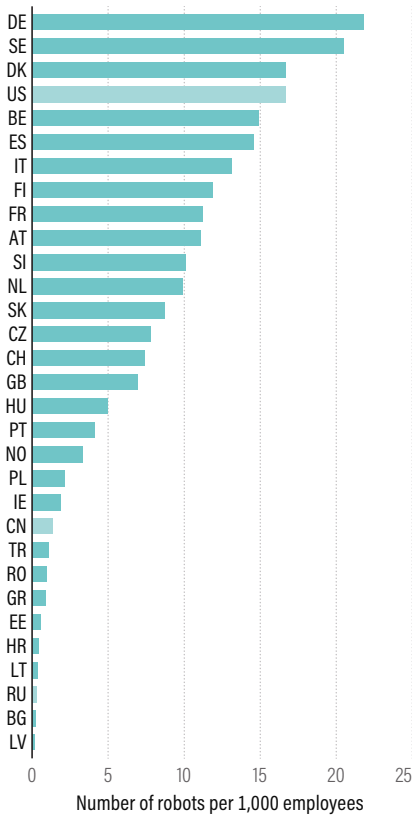
## THE TECHNOLOGY LANDSCAPE IN EUROPE

### How widespread is the use of operational technologies in Europe?

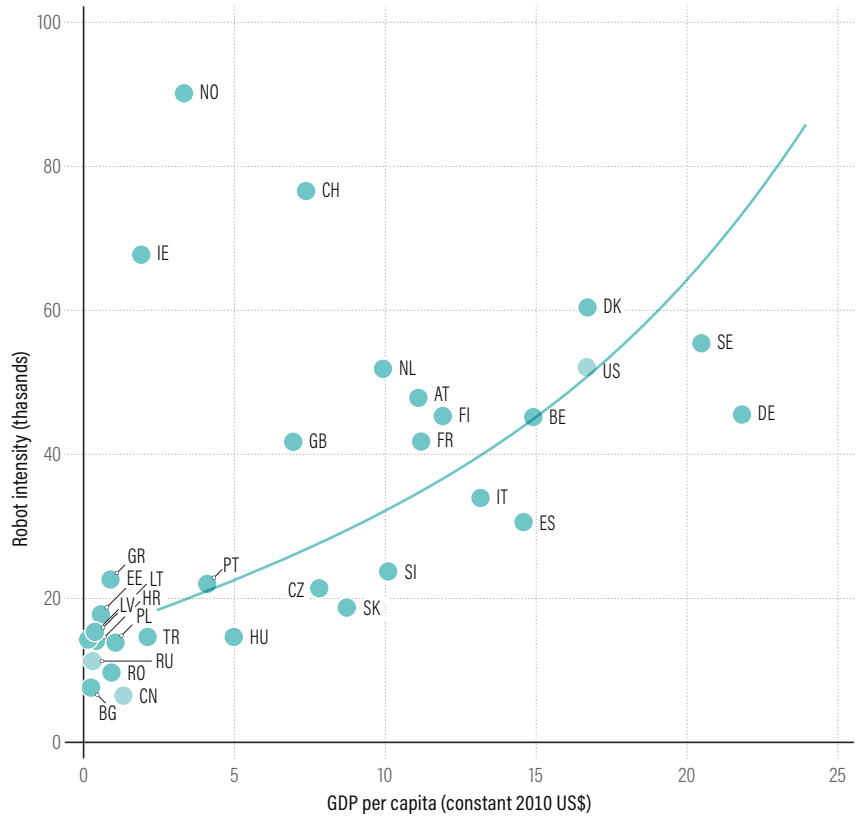
European countries have among the highest intensity of robot use in the world, with most surpassing China and a few in the EU-14 exceeding the United States. Germany, Sweden and Denmark, at 22, 20 and 15 robots per 1,000 workers engaged, had the highest intensity of robot use in 2016 (panel a, Figure 5.1). Other member countries of the EU-14, along with the United States, comprised the top 10 globally, as the intensity of robot use is positively correlated with income per capita (panel b, Figure 5.1). Some EU-13 member countries — Slovenia, the Slovak Republic, the Czech Republic, Hungary and Poland — were also characterized by a high intensity of robot use. At 10 robots per 1,000 workers engaged, Slovenia's intensity of robot use was five times

**FIGURE 5.1** EU-14 countries and the United States have the highest intensity of robot use

a. Robots per 1,000 employees, 2016



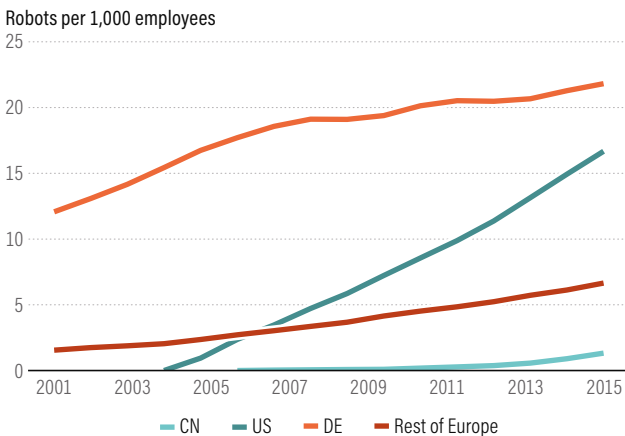
b. Robots per 1,000 employees and GDP per capita, 2016



Source: Authors' calculations based on International Federation of Robotics, World Input-Output Database and World Development Indicators.  
 Note: EU = European Union; GDP = gross domestic product.

**FIGURE 5.2** The United States has seen a far more rapid increase in its intensity of robot use over the past decade relative to Europe

Robots per 1,000 employees, 2000 - 15



Source: Authors' calculations based on International Federation of Robotics and World Input-Output Database

that of China in 2016. The United States has experienced a substantial increase in its intensity of robot use since the early 2000s compared with Germany and other countries in Europe (Figure 5.2).

This leading position of countries in the EU-14 along with the United States in industrial automation is also reflected in the share of firms that use robots in the production process. Based on data from a recent survey conducted by the European Investment Bank (EIB), there are nine countries where the share of manufacturing firms that report the partial or full implementation of advanced robotics in their business is at least 50 percent. These include Slovenia (62 percent), Finland (61 percent), Austria (59 percent), Denmark (55 percent), Sweden (52 percent), Germany (51 percent), and France, Belgium and the United States (50 percent) (EIB, 2019).<sup>3</sup>

The use of industrial robots is concentrated among a few industries in the manufacturing sector. The transportation equipment sector is where the use of industrial robots is most widespread, followed by the manufacture of rubber

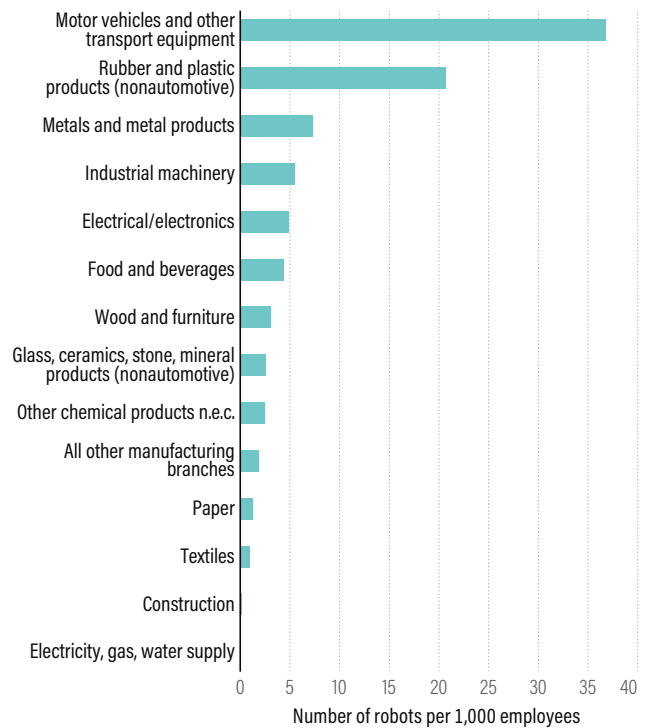
and plastic products, metals and metal products, industrial machinery and electronics (Figure 5.3). The transportation sector stands out having experienced the largest increase in the use of industrial robots among high-income countries in Europe and the United States between 1993 and 2016. At the same time, the use of industrial robots in the manufacture of textiles, apparel and leather products has remained negligible over the same period (Hallward-Driemeier and Nayyar, 2017).

There are many elements to the IoT that make it hard to measure. Machine-to-machine (M2M) devices — a communication technology where data can be transferred with little or no human interaction between devices and applications — is one such element (OECD, 2016). Figure 5.4 shows that Sweden has the highest number of M2M devices per 100 inhabitants deployed, followed by Austria, Italy, New Zealand and the United States. Norway and other member countries of the EU-14 group — Netherlands, Germany, France and Finland — account for the rest of the top 10.<sup>4</sup> In terms of the share of manufacturing sector firms that had fully or partially implemented the IoT<sup>5</sup> in their business, the adoption rate was 60 percent in the United States compared with about 30 percent, on average, in the EU. Barring one exception, this adoption of industrial IoT was lower in the EU country than the United States (EIB, 2019).

3D printing is still in the early stages of being adopted globally. The share of manufacturing sector firms using 3D printing in 2018 ranged from 2 to 17 percent in countries across

**FIGURE 5.3** The use of industrial robots is concentrated among a few manufacturing industries, especially transportation equipment

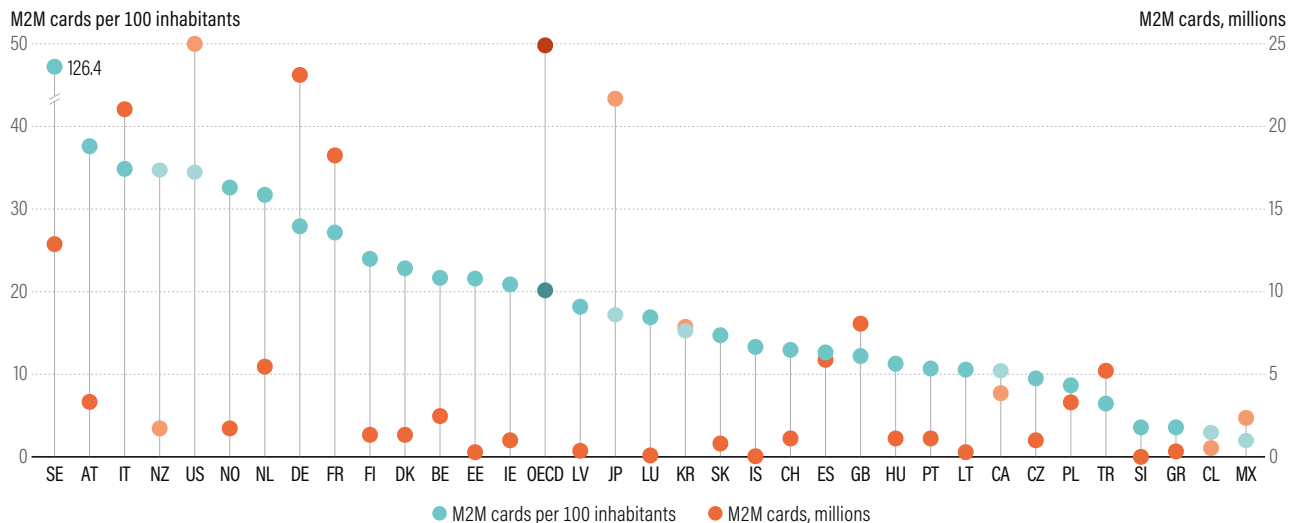
Robots per 1,000 employees, by sector, 2016



Source: Authors' calculations based on International Federation of Robotics.

**FIGURE 5.4** Countries in the EU-14 group have a higher intensity of use of the IoT in Europe, although only a few rank higher than the United States

Stock of commercially deployed M2M devices per 100 inhabitants, 2018



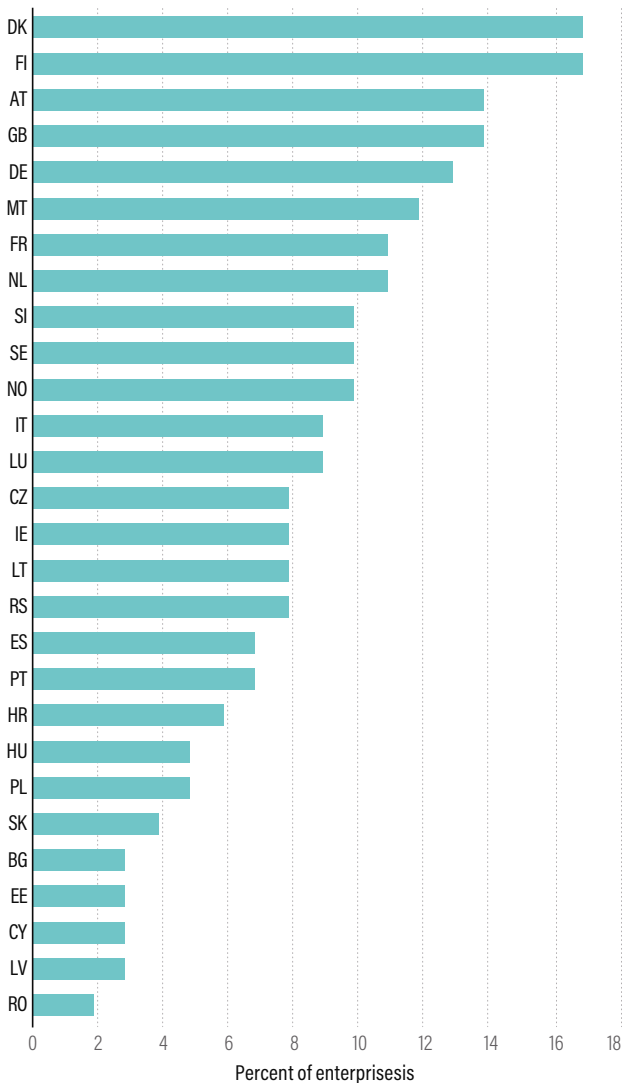
Source: OECD.

Note: EU = European Union; IoT = internet of things; M2M = machine-to-machine.

Europe. As with industrial robots, countries in the EU-14 group come out at the top — Finland and Denmark (17 percent), Austria (14 percent), Germany (13 percent), France and the Netherlands (11 percent), and Sweden and Norway (10 percent) (Figure 5.5).<sup>6</sup> Outside the EU-14, 14 percent of firms in the United Kingdom and 10 percent of firms in Slovenia used 3D printing. Based on a nationally representative survey, the European Investment Bank (EIB) finds that 25 percent of manufacturing sector firms in the EU had partially or wholly implemented 3D printing in their business compared with 30 percent in the United States (EIB, 2019). These low adoption rates might be attributable, at least in part, to the technology’s naissance. Of the large firms that use 3D printing across countries in Europe, only a small share uses the technology to sell even prototypes (Figure 5.6).

**FIGURE 5.5** 3D printing is still in the early stages of being adopted in Europe

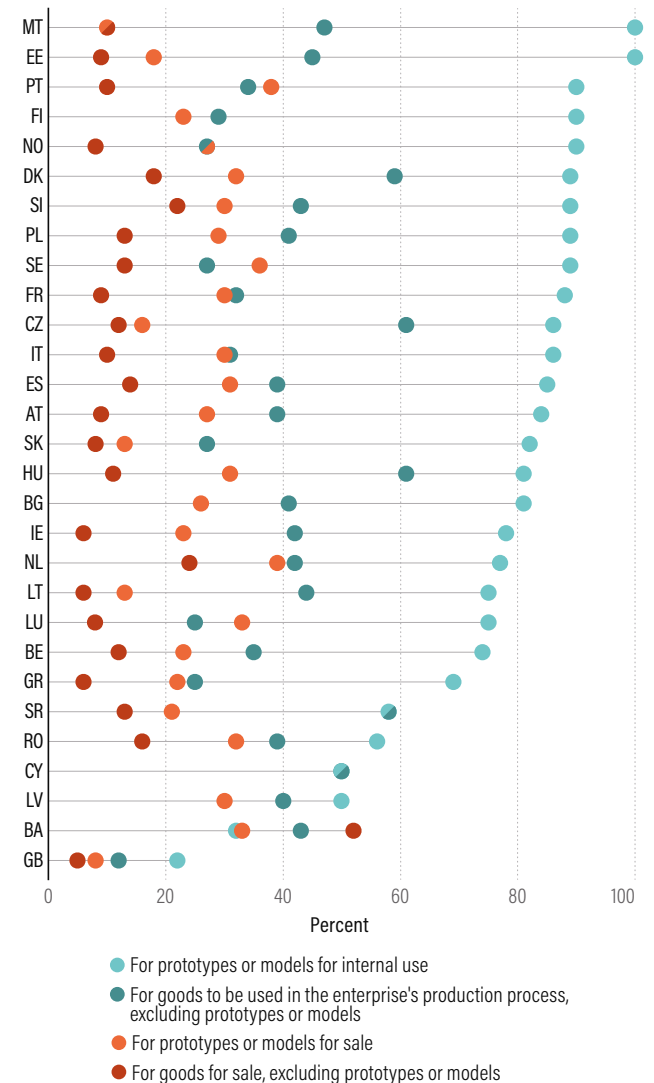
Share of firms in the manufacturing sector using 3D printing, 2018



Source: Eurostat.

**FIGURE 5.6** Most firms in Europe use 3D printing only to develop prototypes or models for internal use

3D printing in large firms, by type of use, 2018



Source: Eurostat.

## Is Europe a global leader in the creation of operational technologies?

Globally, many of the main robot producers are in Europe—these include three each in Denmark and Switzerland, and six in Germany, compared with six in Japan and only one supplier in the United States (Leigh and Kraft, 2018).<sup>7</sup> Germany, in particular, stands out.<sup>8</sup> Five of the 20 largest firms producing industrial robots are originally German (Dauth et al., 2017) and Germany exports almost 75 percent of the robots it produces (Leigh and Kraft, 2018). Italy and France are the other big European players in industrial robotics, while the United Kingdom has a stronghold on robotics applications in health care (Estolatan et al., 2018). The United States, in contrast, imports most of its robots from suppliers in Europe or Japan (Leigh and Kraft, 2018). Europe is also a leader in the development of collaborative robots (cobots)—designed to work together with humans in the same work area, without the need for safety cages. Danish Universal Robots has been a leading player in the development of ‘cobot’ technology since 2009 (Bogue, 2016).<sup>9</sup>

Europe is also on a par with the United States in the development of the IoT, with those in the EU-14 being among the leaders. The OECD (2017) shows that the United States and the EU have the largest shares of patent filings with regard to the IoT—as measured by IP5 families filed at USPTO and EPO—between 2010 and 2012. While the United States and Europe maintain an advantage over China, Japan, and the Republic of Korea, they have lost some ground compared with the previous period from 2005 to 2007.

Firms in Europe could also become world leaders in IoT-based platforms if they adapt their business models much like tech companies in the United States. For example, Apple’s operating margin in its platform-based services—such as Apple Music, Apple Pay, and from the App Store—(62 percent) was significantly higher than in its device sales (34.3 percent). European industrial companies similarly have an enormous installed base of machines whose data they can use in IoT platforms. For example, Siemens optimizes the factory efficiency of its customers by connecting machines to its MindSphere platform. ThyssenKrupp, a manufacturer of elevator and escalator equipment, has connected its installed base of about 180,000 units to its platform MAX, and analyzes the data on equipment usage. These data-driven services reduce downtime by about 50 percent and save costs by optimizing maintenance intervals. Other examples are the platforms Aviator by Lufthansa Technik and Skywise by Airbus. These integrate and analyze data from manufacturers, suppliers and aircraft turbines into a single system to improve business performance. McKinsey Global Institute (2015) estimates that the B2B IoT market will account for about 70 percent of the total IoT market by 2025.<sup>10</sup>

A few countries in Europe are centerstage in the development and operationalization of 3D printing. Germany, the United States, China and Japan have the largest number of additive manufacturing (AM) patents in the world. The European Communities: Technopolis and Fraunhofer report (2017) similarly notes that, with the exception of Germany, most of the major producers of advanced additive manufacturing machinery were based outside Europe (European Communities: Technopolis and Fraunhofer, 2017). More recent information shows that of the top 10 3D printing manufacturers, four are located in the United States, three in Germany, two in Belgium and one in Sweden (Gress and Kalafsky, 2015). Furthermore, other European countries such as the United Kingdom, France and Austria have the highest number of AM patents after the four front runners—Germany, the United States, China and Japan (Abeliansky et al., 2015).

Europe’s success as a pioneer of 3D printing is illustrated by the hearing aids industry, in which nearly 100 percent of production uses this technology. Three major inventions marked a turning point. First, in 2001, two Danish graduate students developed a prototype of a 3D scanner, which was used to scan hearing aid shells (Sandström, 2016). Widex—one of the three Danish hearing aid manufacturers—immediately signed an agreement for the development of a scanner. In addition to the scanner, the students also developed the software and founded 3Shape, a company that now controls 90 percent of the market for scanners and software for 3D printing. Second, a German firm, Dreve Materials, launched in 2002 a biocompatible material suitable for 3D printing processes of hearing aids. Finally, in 2005, EnvisionTEC, a producer of 3D printers, sold its first Selective Modulation printer to the Phonak Group, headquartered in Switzerland, that by 2006 became the largest producer<sup>11</sup> of 3D printed hearing aids (Freund et al., 2019).

# OPERATIONAL TECHNOLOGIES AND EUROPE'S ECONOMIC COMPETITIVENESS

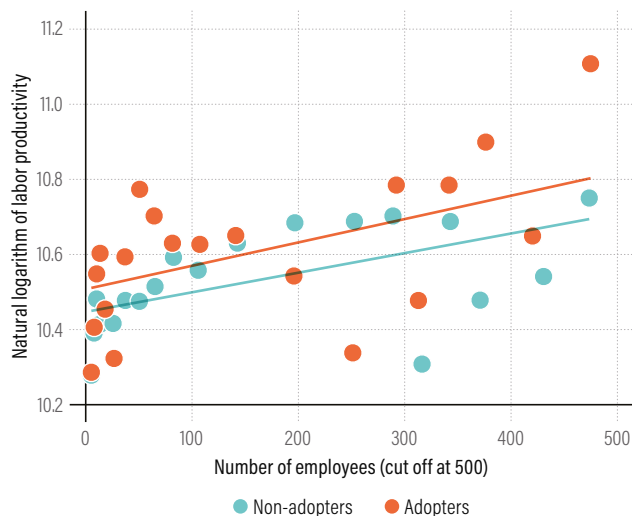
## Is the use of operational technologies associated with higher levels of productivity in Europe?

There is preliminary evidence suggesting that the use of industrial robots has contributed to productivity improvements in Europe. For a sample of 17 advanced economies in Europe, Graetz and Michaels (2018) show that the use of industrial robots raised annual labor productivity growth by 0.36 of a percentage point between 1993 and 2007 (compared with mean growth of 2.4 percent). This represented 16 percent of labor productivity growth during that period. Autor and Salomons (2018) find that, on average, from 1993 to 2007, one additional robot per 1,000 workers is associated with a statistically significant increase in total factor productivity (TFP) (0.175 log points) considering 16 industries in 18 OECD countries. Using firm-level data from the European Manufacturing Survey across seven countries, the European Commission (2016) finds that the use of industrial robots is positively associated with significantly higher labor productivity. Studying local labor markets in Germany, Dauth et al. (2017) find that for every additional robot per 1,000 workers, local GDP growth per person employed increases by 0.5 percent.

The productivity-enhancing impact of industrial automation in Europe is also reflected in its diverging relationship with manufacturing value added and employment. Analyzing 64 countries from 2005 to 2014, Mayer (2018) finds that an increase in industrial robot installation and stock is associated with an increase in the share of manufacturing in total value added. European countries such as the Czech Republic and Slovakia, which experienced a relatively large uptake of robot use, also experienced a relatively large increase of their manufacturing sector's share in value added. At the same time, Mayer (2018) finds a negative relationship between the increased density of industrial robot use and the contribution of countries' manufacturing sectors to total employment. Sweden and Slovenia stand out as countries with high robot density and a marked decline in the contribution of the manufacturing sector to total employment.

**FIGURE 5.7** For a given firm size category, firms that adopted the IoT are more productive than firms that did not

Labor productivity by firm size (number of employees) and adoption of the IoT, 2019



Source: EIB-WBG background paper by Cathles, Nayyar, and Rückert (2020).

Note: IoT = internet of things. Firms are weighted with value added. This bins scatter plot groups the number of employees into equal-sized bins (default = 20), and then computes the means for firm size and log labor productivity within each bin.

relationship between the increased density of industrial robot use and the contribution of countries' manufacturing sectors to total employment. Sweden and Slovenia stand out as countries with high robot density and a marked decline in the contribution of the manufacturing sector to total employment.

There is also some evidence to suggest that adoption of 3D printing and the IoT has improved the performance of European firms. Based on survey data from 124 medium and large automotive manufacturers in Europe,<sup>12</sup> Delic et al. (2019) find that the adoption of additive manufacturing is positively associated with supply chain performance. This positive effect of 3D printing seems to be primarily driven by increasing the reliability and speed with which firms can fulfill orders for existing and new products. Furthermore, case studies have estimated that the IoT reduces costs, on average, by 18 percent for industrial adopters which, in turn, are expected to increase firm profits (OECD, 2017). Recent EIB survey data across the EU and the United States indicate that the partial or full implementation of 3D printing and the IoT is positively related to firm-level labor productivity (Annex 5, Table A5.1).<sup>13</sup> In fact, for a given firm size category, technology adopters are more productive than non-adopters (Figure 5.7).



## Is the use of operational technologies associated with reshoring to, or less offshoring from, Europe?

Automation-led productivity improvements can result in the reshoring of labor-intensive manufacturing to high-income economies. By reducing the relative importance of wage competitiveness, robotics and ‘smart’ factories can change what it takes for locations to be competitive in the global market for manufactures. The quality of infrastructure and logistics, regulatory requirements, the density of the supply base, workforce skills and information flows are becoming increasingly important in reducing time to market and responding to changing customer needs. The generation of data and their subsequent use in ‘smart’ factories emphasize the servicification of manufacturing, which can further reduce the importance of labor costs in determining competitiveness. For example, advanced data analytics will enable the use of real-time information collected through sensors to optimize ‘smart’ production processes (Van der Marel, 2016; Dijcks, 2013; Opresnik and Taisch, 2015). If industrial automation makes it more efficient to rebundle activities in ‘smart’ factories, it may result in the reshoring of production to high-income economies.

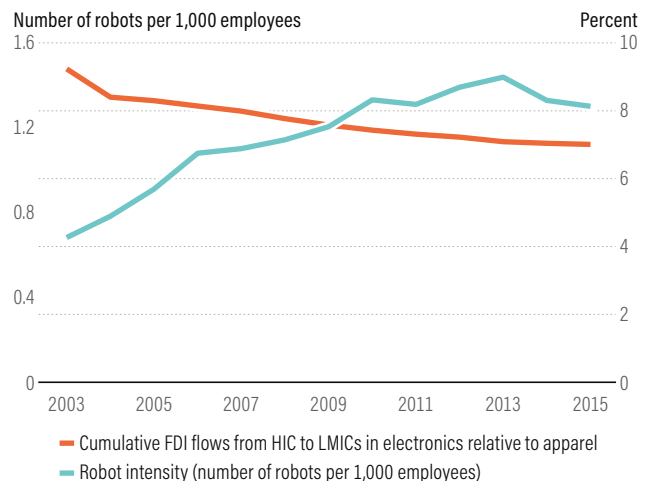
There is an increasing amount of anecdotal evidence to suggest that industrial automation has already enabled such reshoring to high-income economies, including in Europe. Adidas, the German sporting goods company, had established ‘speed factories’ in Ansbach, Germany, and Atlanta, the United States, which use computerized knitting, robotic cutting, and 3D printing almost exclusively to produce athletic footwear (Assembly, 2012; Bloomberg, 2012; Economist, 2017a, 2017b; Financial Times, 2016). Foxconn, the world’s largest contract electronics manufacturer best known for manufacturing Apple’s iPhone, has recently announced it will spend US\$40 million at a new factory in Pennsylvania, using advanced robots and creating 500 jobs (Lewis, 2014). A report by Citigroup and the University of Oxford’s Martin School finds that 70 percent of Citi institutional clients surveyed believe that automation will encourage leading companies to reshore manufacturing closer to home (Citigroup, 2016).

However, the available evidence suggests that reports about the advent of reshoring to Europe are greatly exaggerated. Longitudinal data from the German Manufacturing Survey (individual survey waves in 1997, 1999, 2001, 2003, 2006, 2009, and 2012) show that about 2 percent of all manufacturing firms were active in reshoring between 2010 and mid-2012—a percentage that seems, surprisingly, to be decreasing. Similarly, survey data for Austria, Denmark, France, Germany, Hungary, Portugal, the Netherlands, Slovenia, Spain, Sweden and Switzerland show that only around 4 percent of firms have moved production activities back home—much lower than the 17 percent of firms that offshored activities in the decade before. For every backshoring company, there are more than three offshoring companies (De Backer et al., 2016). Ancarani et al. (2019) studied 495 backshoring firms headquartered in Europe and found that only 14 percent of those firms adopted either 3D printing or advanced automation following reshoring.

More systematic evidence also does not reflect a positive (negative) impact of automation on reshoring (offshoring). There is a negative association between the intensity in robot use in high-income countries (HICs) and the flow of FDI from HICs to low- to middle-income countries (LMICs), when measured as a ratio between the most (electronics) and the least (apparel) automated industries (Figure 5.8). This correlation, however, does not amount to causality. Hallward-Driemeier and Nayyar (2019) find that the intensity of robot

**FIGURE 5.8** The intensity in robot use in HICs is negatively associated with the flow of FDI from HICs to LMICs

Ratio of robot stock per 1,000 employees in electronics (most automated) to apparel (least automated) in HICs and ratio of cumulative FDI flows in electronics to apparel from HICs to LMICs, 2003–15



Source: Hallward-Driemeier and Nayyar (2019).

Note: FDI = foreign direct investment; HICs = high-income countries; LMICs = low- and middle-income countries.



use in HICs had a positive impact on cumulative flows of greenfield FDI from HICs to LMICs between 2004 and 2015. Similarly, Artuc, Bastos and Rijkers (2019) show that a 10-percentage-point increase in robot density in developed countries is associated with a 6.1-percentage-point increase in their imports from less developed countries, and an 11.8-percentage-point increase in their exports to these countries, such that net imports from the South within the same sector declined by 5.7 percentage points.<sup>14</sup> At the firm level, the intensity of robot use shows no statistically significant effect on the relocating of manufacturing activities outside Europe (European Commission, 2016).

Scale is expected to matter less with 3D printers, whereby even small businesses in remote locations can access international designs and print them locally. This scenario of geographically dispersed manufacturing activity, however, might be constrained by the scarcity of trained technicians and engineers, or by reliable electricity supply. The weak protection of intellectual property rights is another factor: firms will be unlikely to send designs to places where they can easily be printed without limit for customers not paying license fees or royalties. Furthermore, countries that are not open to trade in services risk being left behind because the 3D printing model effectively substitutes trade in services for goods trade. Either given these limitations on the capabilities to use 3D printing or if scale economies in 3D printing itself turn out to be strong, printing activity will likely cluster in hub locations close to major markets in Europe, North America and Asia (Hallward-Driemeier and Nayyar, 2017). This is important for Europe, which accounts for 50 percent of world exports in hearing aids that are entirely 3D printed (Freund et al., 2019).

The 3D printing of hearing aids (and similar goods) has not shifted production closer to consumers and the early innovators in Europe remain the major export platforms. 3D printers transformed the hearing aid industry in less than 500 days across the mid-2000s, which makes this product a unique natural experiment to assess the trade effects of this technology. Comparing growth in hearing aid trade with other similar products and controlling for a range of other relevant variables that might have changed during this period, Freund et al. (2019) find that 3D printing led to an increase in trade of 58 percent over nearly a decade. They also indicate that there is no reversal in comparative advantage and early innovators in Europe, such as Denmark and Switzerland, remain the main export platforms. Some middle-income economies, such as China, Mexico and Vietnam, have also been able to substantially increase their market shares between 1995 and 2015. Beyond hearing aids, Freund et al. (2019) find that 35 products that are increasingly being 3D printed have also experienced faster trade growth relative to other similar goods.

There is some early evidence suggesting that industrial automation in HICs might change global trade and investment patterns in the future. Exploiting differences across countries and industries, Hallward-Driemeier and Nayyar (2019) find that, past a threshold level, the increasing number of robots per 1,000 employees in HICs is negatively associated with the growth rate of the stock of outbound FDI from HICs to LMICs. However, only about one-third of the sample exceeds the threshold level of robots per 1,000 employees, beyond which further automation results in a decline or deceleration in FDI growth. Based on data for 3,313 manufacturing companies across seven European countries, Kinkel, Jager and Zanker (2015) find that firms using industrial robots are less likely to offshore production activities outside Europe. Among a set of 35 products that are increasingly being 3D printed, Freund et al. (2019) find some evidence of a reversal of comparative advantage. The positive effect of 3D printing on trade decreases with product weight and could even reverse for bulky products. This suggests that the technology may be used to produce goods closer to consumers for products with high transport costs.

# OPERATIONAL TECHNOLOGIES AND MARKET INCLUSION IN EUROPE

## Is the use of operational technologies biased toward large firms?

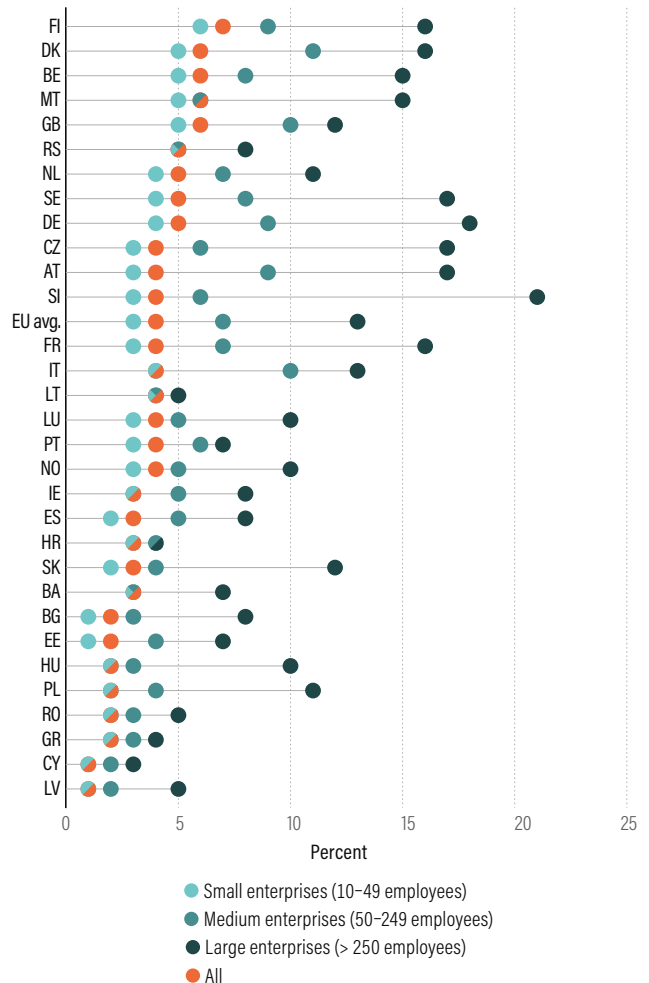
The use of industrial robots in Europe increases with firm size. Using data from the 2012 European Manufacturing Survey in seven European countries, the European Commission (2016) finds that, while one-quarter (24 percent) of the smallest firms surveyed (between 20 and 50 employees) reported using industrial robots, this jumps to 70 percent in the largest firms surveyed (1,000 or more employees). The European Commission (2016) identifies batch size of production and export activity as other firm-level determinants of the probability of industrial robot use. Firm size matters for technology creation too. For example, in Italy—the second-largest producer of industrial robots in Europe—robotics producers are overwhelmingly large firms (75 percent) and very few small firms (less than 10 percent) (Estolatan et al., 2018).

Scale is expected to matter less with 3D printers, whereby even small firms can access international designs and print them locally. However, available evidence from European countries where the use of 3D printing is most widespread—Finland, Belgium, the United Kingdom, the Netherlands and Germany—about 5 percent of all firms used 3D printing in 2018 compared with 15 percent of large firms (Figure 5.9). This suggests that 3D printing does not reduce the importance of scale, because it requires a large investment in technology and machinery, and the presence of highly specialized inputs and services. Recent EIB survey data (2019) also show that partial or full implementation of the IoT systematically increases with firm size in the EU (EIB, 2019).

Furthermore, the use of industrial robots widens the performance gap between large and small firms. Figure 5.10 illustrates this for the intensity in robot use. In motor-vehicle manufacturing—the sector where this technology is most widespread—countries with a higher intensity of robot use are also characterized by a larger gap in labor productivity between large and small firms. For example, labor productivity in large firms is more than double that of small firms in Germany, where the intensity of automation is around 100 robots per 1,000 workers. In contrast, labor productivity in large and small firms is about the same in Greece, where the corresponding intensity of robot use is close to zero. There is, however, no such relationship in the apparel sector, which uses this technology the least. This result is consistent with the fact that, much like other physical capital, the cost of implementing a robot application is largely fixed in nature and later installations of the same type can be made for a fraction of the initial cost. These fixed costs are a source of significant economies of scale in robot use, which is likely to benefit larger enterprises.

**FIGURE 5.9** A larger share of large firms, relative to SMEs, uses 3D printing

Share of firms that use 3D printing, 2018



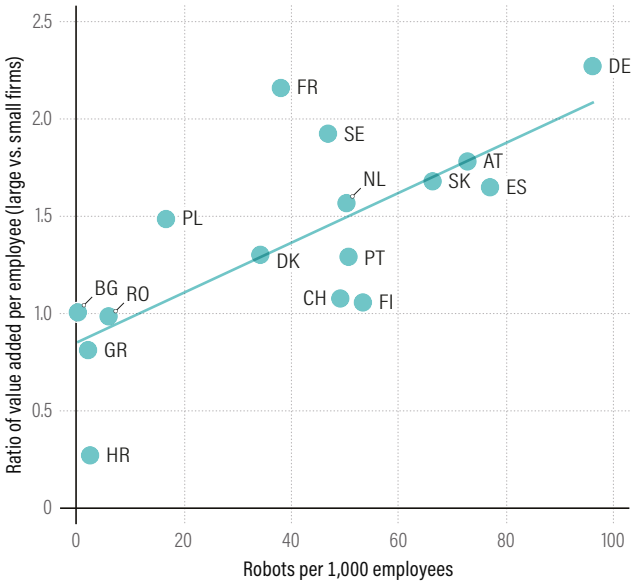
Source: Eurostat.

Note: SME = small and medium enterprises.

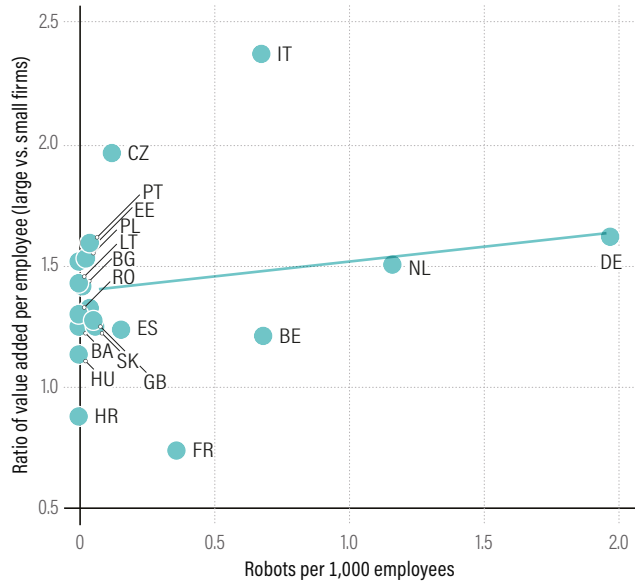
**FIGURE 5.10** The intensity of robot use widens the performance gap between large and small firms

Robots per 1,000 employees and the ratio of value added per worker in large vs. small firms, 2016

a. The intensity of robot use is associated with a productivity gap between large and small firms in the motor vehicles industry, where this technology is more widespread



b. There is no association between the intensity of robot use and the productivity gap between large and small firms in the apparel industry, where this technology is least widespread



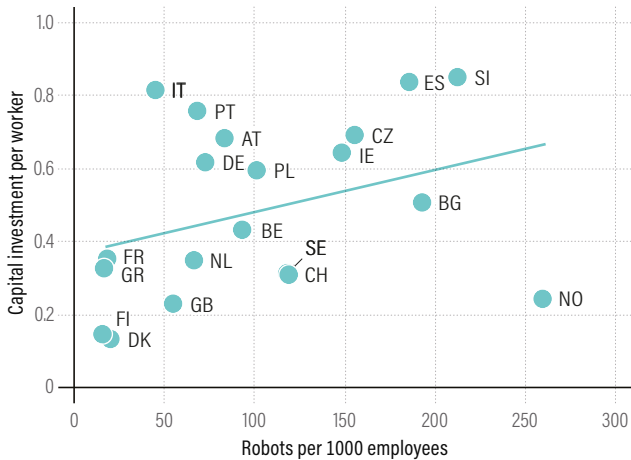
Source: Authors' calculations based on Eurostat.

The diffusion of ‘collaborative’ industrial robots (‘cobots’) might provide a lower-cost opportunity to become first-time robotics technology adopters. Compared with traditional robots, cobots entail lower costs for installation and smaller capital investments with shorter payback periods. According to Bogue (2016), these features will make cobots attractive to SMEs that might find traditional robot adoption cost prohibitive. Bogue

indicates that cobot development in the European market will depend, at least in part, on the 2.3 million SMEs operating in the manufacturing sector.

**FIGURE 5.11** The intensity of robot use is positively associated with capital intensity in production

Robots per 1,000 employees and capital investment per worker, 2016. Ratio between most (motor vehicles) and least technology-intensive sectors (apparel)



Source: Authors' calculations based on Eurostat.

## Is the use of operational technologies associated with fewer jobs?

Operational technologies, by definition, displace labor as they automate certain tasks. The intensity of robot use is, not surprisingly, associated with higher capital intensity in production. Measured as the ratio between motor-vehicle manufacturing and apparel manufacturing—sectors where this technology is, respectively, the most and least widespread—countries with a higher intensity of robot use are also characterized by higher capital investment per worker (Figure 5.11). However, this association does not consider the fact that productivity improvements due to new machines may expand employment in other tasks, either in the industries undergoing automation or elsewhere (Autor, 2013). For example, the number of industrial robots per 1,000 workers in Germany is almost four times the robot intensity in the

United States. Despite this, the manufacturing sector in Germany accounted for one-quarter (25 percent) of employment in 2014, compared with 9 percent in the United States (Dauth et al., 2017).

The negative displacement effect of automation may be outweighed by productivity gains that increase the demand for labor, including in complementary tasks. Productivity growth resulting from automation will generally lead to lower prices and, if the quantity demanded increases,<sup>15</sup> the volume of goods sold could so increase that more rather than fewer workers would ultimately be employed. The expansion of automated teller machines (ATMs) in the United States, which quadrupled from about 100,000 in 1995 to 400,000 in 2010, is a much-cited example. These machines did not eliminate bank tellers; their numbers actually increased modestly from 500,000 to about 550,000 between 1980 and 2010. By reducing the cost of operating a bank branch, ATMs indirectly increased the demand for tellers.<sup>16</sup> Furthermore, as routine cash-handling tasks receded, computerization enabled a broader range of bank teller to become involved in new ‘relationship banking’ tasks.<sup>17</sup>

Recent estimates, which combine the negative displacement and positive productivity effects of industrial robots on local labor markets, range from a mild negative to a positive impact. Acemoglu and Restrepo (2017) find that the use of one more robot per 1,000 workers reduced the aggregate employment to population ratio by about 0.34 of a percentage point from 1990 to 2007 in the United States. This amounts to one new robot reducing employment by 5.6 workers. However, for a broader sample of countries that also includes those in Western Europe, Australia, Japan and the Republic of Korea, Autor and Salomons (2018) find that, while increased automation leads to employment decreases within industries, the countervailing effect of increased value added and employment gains in other industries (particularly in consumer industries) offsets the loss of own-industry employment, in the aggregate. Similarly, Dauth et al. (2017) find that each new robot in Germany eliminates roughly two manufacturing jobs, but that this loss is fully offset by jobs gained in the services sector.<sup>18</sup>

The aggregate impact notwithstanding, the use of industrial robots has changed the composition of employment in terms of sectors, tasks, and skills. Analyzing 64 countries from 2005 to 2014, Mayer (2018) finds a negative relationship between increased robotics and the contribution of countries’ manufacturing sectors to total employment. Using individual worker biographies over time, Dauth et al. (2017) find that the decline in employment in Germany’s manufacturing sector associated with robots does not come from displaced incumbent workers, but from fewer new jobs. Within firms, based on data from the European Manufacturing Survey, the European Commission (2016) shows that the use of industrial robots is not associated with lower overall employment, which might reflect a reallocation of jobs across tasks. Graetz and Michaels (2018) find significant negative implications of robot use for the employment of low-skilled workers for a sample of 17 advanced economies in Europe between 1993 and 2007.

Industrial automation has also resulted in a declining labor share of value added. The Acemoglu and Restrepo (2017) study for the United States finds a reduction in wages of less than 1 percent across 1,000 workers owing to robotization. In a study of the Netherlands, Bessen et al. (2019) find that the decline in wages resulting from automation is attributable to a decline in the hours worked rather than in the wages rate.<sup>19</sup> Based on a larger sample across Europe, Graetz and Michaels (2018) claim that while wages increase with robot use, the number of hours worked for low and mid-skill labor decreases. Evidence from Germany suggests that workers’ wages are not keeping pace with productivity gains from robotization, thereby contributing to the declining income share of labor (Dauth et al., 2017). Furthermore, based on a sample of 28 industries in 18 OECD countries<sup>20</sup> between 1970 and 2007, Autor and Salomons (2018) find that the own-industry decline in labor’s share of value added is not compensated by other industries. Therefore, labor’s share of value added has declined over time even in the aggregate.

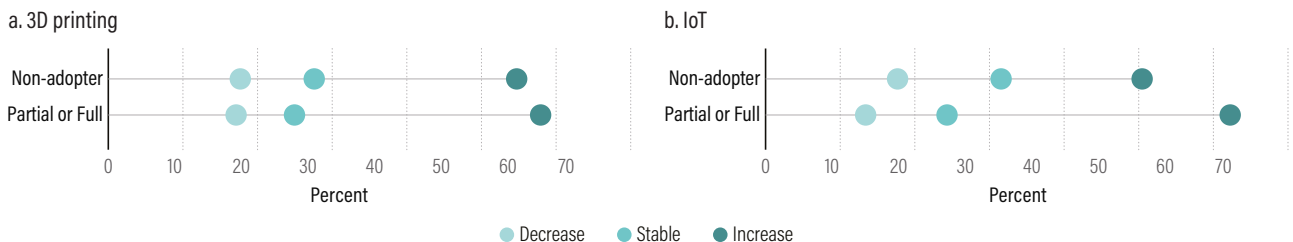
As a result, there might be growing inequality concerns owing to significant challenges in workers adjusting to the automation-induced disruption. In a forecasting exercise, Berg et al. (2018) find that robots will be good for growth, but bad for inequality. The various scenarios of their model show that when robots are best for growth (i.e., GDP increases the most) and when the pie becomes biggest, labor receives a smaller slice of the pie, exacerbating inequality. These forecasts offer an important nuance that, while labor displacement in certain tasks and industries can eventually be counteracted, the process could take time and low-skill workers would suffer more under higher-growth scenarios. Freeman (2015) similarly foresees increased inequality and that the biggest rents will go to the people who own the capital (robots).

The industrial structure of economies will likely mediate the impact of industrial automation on jobs in Europe. Schlogl and Summer (2018) make the case that HICs will be less susceptible to employment loss due to industrial automation because a large part of the workforce is employed in the services sector. Therefore, European economies that do not have thriving service sectors, or currently lag behind the frontrunners, may face greater adjustments to their employment structure.

There are also increasing complementarities between operational technologies and the demand for labor with the development of ‘cobots’. Anecdotal evidence, such as from Mercedes-Benz, BMW, and the SEW-Eurodrive factory in the automobile sector, increasingly illustrates that firms are finding ‘human robot’ teams more productive than either humans or robots separately. Forecasts (by Barclays) project a large growth in this ‘cobot’ market. Cobots are much more affordable than their industrial robot counterparts that typically operate in cages separately from humans (FT, 2016). Furthermore, the limitations of robotics in both high-payload and light-duty payload situations makes the idea of collaborative robots without all the safety fencing appealing in a variety of industrial contexts to both executives and workers alike (Shikany, 2014).

The relationship between other operational technologies, such as 3D printing and the IoT, and jobs is less well explored. Recent EIB survey data show that about 60 percent of firms that partially or fully implemented 3D printing in their business in the EU experienced an increase in employment growth over the past three years, compared with 50 percent of firms that did not adopt these technologies. Similarly, a little less than 20 percent of firms among both adopters and non-adopters experienced a decline in employment growth (panel a, Figure 5.12). The trends are broadly similar for the IoT (panel b, Figure 5.12). In fact, the positive association between the adoption of the IoT and employment growth is robust to the inclusion of other firm characteristics, such as size, age, and exporting status, as well as country- and industry-specific factors (Annex 5, Table A5.2).

**FIGURE 5.12** Trends in employment growth in the EU over the past three years, by 3D printing and the IoT, 2019



Source: EIB-WBG background paper by Cathles, Nayyar, and Rückert (2020)  
 Note: EU = European Union; IoT = internet of things.

## OPERATIONAL TECHNOLOGIES AND GEOGRAPHIC CONVERGENCE IN EUROPE

### Is the use of operational technologies associated with a higher spatial concentration of economic activity in certain European regions?

Increased robotization among Europe’s HICs has not resulted in nearshoring to lower-income countries in the region. Exploiting differences across countries and industries, Hallward-Driemeier and Nayyar (2019) find that the intensity of robot use in HICs had a positive impact on cumulative flows of greenfield FDI from HICs to LMICs between 2004 and 2015. At the same time, the authors find that the intensity of robot use is negatively associated with the share of FDI going to LMICs in the same ‘region’ when the sample is restricted to countries in the Europe and Central Asia region (Figure 5.13). This suggests that robotization among Europe’s HICs



has been associated with the opposite of ‘nearshoring’ and perhaps is indicative of the fact that wages among LMICs in Europe were high relative to others.

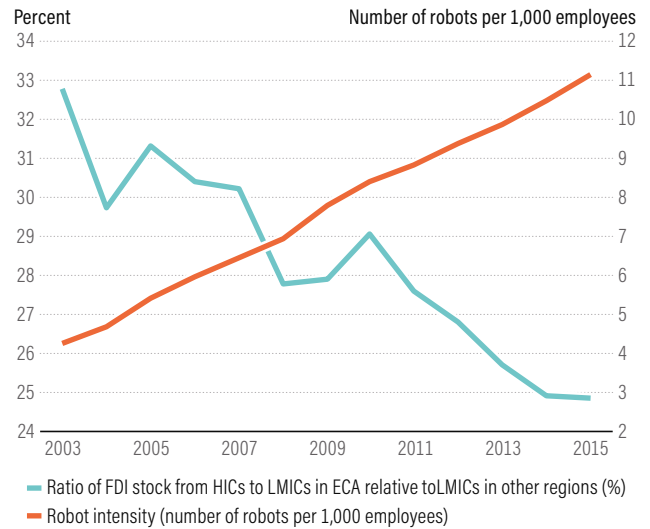
Furthermore, China is rapidly automating production through robotization to address declining wage competitiveness, which in turn could affect nearshoring to countries in Europe. Mayer (2018) therefore argues that automotive industries in Central European countries that are supplying inputs to leading firms in Germany (i.e., the Czech Republic, Slovakia and Slovenia) need to robotize more to remain competitive. In fact, Adidas announced in late 2019 that its ‘Speedfactories’ in Ansbach in Germany and Atlanta in the United States – which use computerized knitting, robotic cutting, and 3D printing to produce athletic footwear – will be moved to China and Vietnam, where 90 percent of Adidas’ suppliers are currently located.

Within countries, evidence from the United States suggests that the use of robots tends to be clustered, congregating densely in some regions but hardly found in others. Industrial robots are clustered heavily in just 10 mid-western and southern states, led by Michigan (which accounts for nearly 28,000 robots, 12 percent of the nation’s total), Ohio (20,400, 8.7 percent), and Indiana (19,400, 8.3 percent), followed closely by Tennessee (Dahlin, 2019). Within these states, the list of the most robot-exposed (larger and smaller) metropolitan areas is similarly concentrated.<sup>21</sup> There are currently 35 smaller metropolitan areas where the robot count exceeds five per 1,000 workers and 56 where it exceeds three per 1,000 workers. Conversely, the robot incidence is less than two per 1,000 workers in 253 metropolitan areas (Muro, 2017).

This clustering in the use of industrial robots reflects existing industrial structures and will therefore reinforce existing patterns in the spatial distribution of economic activity. The uneven map of the use of industrial robots in the United States follows logically from the fact that the auto industry – highly concentrated in the Midwest and upper South – currently employs nearly half of all industrial robots in use. In Germany too, the automobile industry has by far the most industrial robots and is highly spatially concentrated (Dauth et al., 2017). This clustering makes a simple point about operational technologies: their use will be determined by existing production patterns as they are shaped by the local industry mix, skills, and location. In other words, they are unlikely to reduce the concentration of economic activity within countries. This is reflected in Figure 5.14, where the intensity of robot use is not negatively associated with a subsequent change in the spatial concentration of firms across European countries in the auto industry where this technology is most widespread.

**FIGURE 5.13** The intensity of robot use in Europe’s HICs is negatively associated with the share of FDI going from HICs to LMICs in the Europe and Central Asia (ECA) region

Robots per 1,000 employees among HICs in ECA and the ratio of FDI stock from HICs in ECA to LMICs in ECA relative to LMICs in other regions

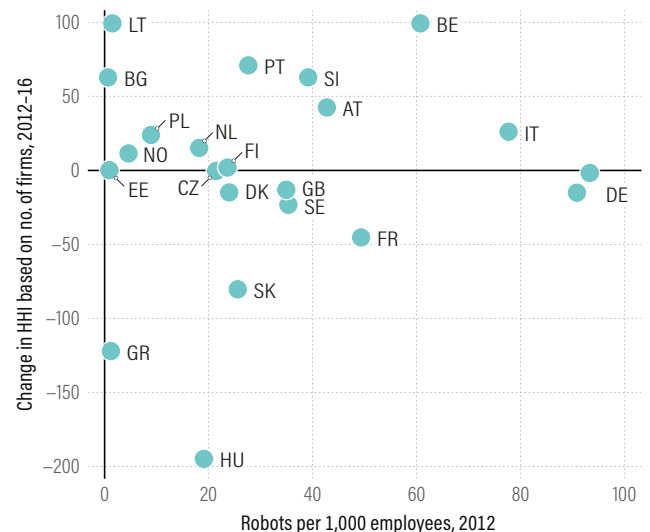


Source: Hallward-Driemeier and Nayyar (2019).

Note: ECA = Europe and Central Asia; FDI = foreign direct investment; HICs = high-income countries; LMICs = low- and middle-income countries.

**FIGURE 5.14** There is no association between the intensity of robot use and subsequent change in the spatial concentration in the motor vehicles industry where this technology is most widespread

Robots per 1,000 employees in 2012 and the change in the Herfindahl Index of Concentration at the NUTS2 level in Europe, 2012–16



Source: Authors’ calculations based on Eurostat.

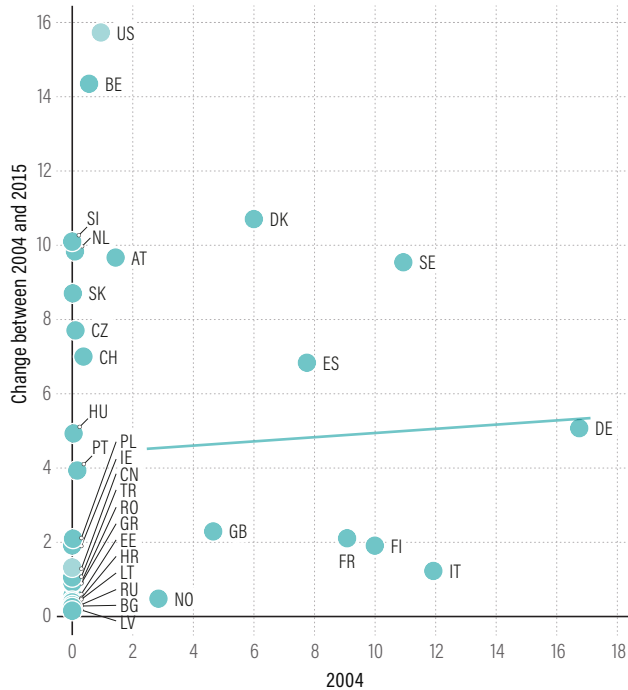
Note: HHI = Herfindahl-Hirschman Index; NUTS = Nomenclature of Territorial Units for Statistics. The Herfindahl Index of Concentration is based on the number of firms/employees at the NUTS2 level.

In certain instances, the use of industrial robots may have the potential to reduce the spatial concentration of economic activity within countries. Take retail services, for instance. The use of robotics is gathering momentum in different parts of the supply chain, including inventory management and home delivery. Amazon, for example, now has around 45,000 autonomous retail service robots to improve inventory management in warehouses (Brynjolfsson and McAfee, 2017). This substitution of labor implies that warehouses can be in remote regions where land is abundant and labor scarce. The use of (transportation) robots in the delivery process itself can further incentivize firms to locate warehouses in remote regions because the technology will make it possible to overcome distance more easily. Amazon, for example, completed its first successful drone delivery in the United Kingdom in late 2016. Other firms such as Flirtey and 7-Eleven are also expanding their drone delivery pilot programs in the United States (O’Shea, 2017).

## Is the technology itself concentrated in some European regions?

There is no systematic evidence of convergence in the use of operational technologies across countries in Europe. Some countries that were characterized by the highest intensity of robot use in 2004 experienced the smallest increase in this intensity between 2004 and 2016 and vice-versa.

**FIGURE 5.15** There is little evidence of catch-up in the intensity of robot use across countries in Europe  
Robots per 1,000 employees, level in 2004 vs. change in 2004 - 16



Source: Authors’ calculations based on International Federation of Robotics.

Finland and Italy on one end of the spectrum and Belgium and Slovenia on the other end, stand out. This evidence indicative of catch-up, however, is not uniform. On the one hand, Denmark and Sweden had among the highest number robots per 1,000 workers engaged in 2004 but also experienced among the highest increases in this intensity of robot use between 2004 and 2016. On the other hand, Poland and Turkey had among the lowest intensity of robot use in 2004, which also increased negligibly over the next decade (Figure 5.15).

There are also differences across countries in Europe with respect to their potential future participation in the development of operational technologies. Germany accounts for about half of the top 20 EU regions with the highest potential to develop patents in additive manufacturing (3D printing), autonomous robots, autonomous vehicles (self-driving cars), and systems integration/the IoT.<sup>22</sup> Most European countries are rarely mentioned in these top 20 rankings, which reflects the concentration of technological potential to develop operational technologies (Boschma and Balland, 2019). Most of the 389 IoT clusters, comprising firms, academia and research centers in the EU are concentrated among a few member countries — Spain (46), Germany (28), Italy (24), France (23) and Belgium (15). Furthermore, the number of IoT enterprises in the EU increased substantially from 2012 to 2017, which was largely attributable

to start-ups, which more than doubled between 2014 and 2016. These IoT start-ups are also concentrated in France, Germany, Spain, Italy and the United Kingdom (European Commission, 2019).

There is a clustering of regions with regard to the production and commercialization of operational technologies within countries too. European Communities: Technopolis and Fraunhofer (2017) finds that more than 50 percent of patent applications in photonics, laser applications and additive manufacturing are concentrated in the top 10 regions — Southern Germany, Île de France, Noord-Brabant, and Northern Italy dominate. Among German regions, Oberbayern and Stuttgart show the highest potential for developing operational technologies



(Boschma and Balland, 2019). Evidence from Italy, the second-largest producer of industrial robots in Europe, suggests that producers are geographically concentrated in northern Italy—the Piedmont and Lombardy regions account for almost 60 percent of Italian firms producing robots (Estolatan et al., 2018). Leigh and Kraft (2018) postulate that the collocation of robotics supplier firms (the ones developing the technology) near knowledge and innovation hubs is not accidental because software technologies are increasingly relevant for robotics.

## CONCLUSION

European countries are among the most intensive users of operational technologies in the world, and a few in the EU-14 are global leaders in their development and operationalization. While members of the EU-14 and the United States comprise the top 10 countries with the highest intensity of robot use, others in Europe are also catching up. Some EU-13 member countries in particular—Slovenia, the Slovak Republic, the Czech Republic, Hungary and Poland—have experienced high rates of growth in the intensity of robot over the past decade or so, and rank higher than China. What is more, many of the leading manufacturers of robots and 3D printers are in Germany, Denmark, Belgium and Sweden. Germany, in particular, stands out. Five of the 20 largest firms producing industrial robots are originally German. And Germany along with the United States, China and Japan have the largest number of additive manufacturing patents in the world.

Europe's edge in operational technologies can be furthered by digital IoT platforms that improve the value of traditional goods, which are at the core of European industry. Platform-based applications are becoming a differentiating factor in the industrial sector, as illustrated by the success of large tech companies in the United States, such as Microsoft and Apple. The industrial IoT, which is estimated to be the largest area of the IoT market in the future, offers enormous economic potential for European industrial companies in this regard. With a large installed base, sensors and programming interfaces in physical objects such as machines, plants, or vehicles can produce an immense amount of data. These data, in turn, can form the basis of IoT platforms that sell information-based solution services.

Industrial automation has raised labor productivity and TFP growth in Europe. Despite this, there is little evidence of reshoring. The increase in the intensity of robot use among Europe's HICs is positively associated with imports from, and cumulative flows of greenfield FDI to, LMICs. There is only some early evidence that shows that past a threshold level of robots per 1,000 workers, automation in Europe's HICs might result in reduced offshoring to LMICs. Similarly, 3D printing has not shifted production closer to consumers. The early innovators, many of whom are in Europe, remain the major export platforms although some middle-income economies such as China have substantially increased their global market shares owing to 3D printing technology.

Operational technologies intensive in physical capital are associated with scale economies and therefore benefit larger enterprises. The use of industrial robots and 3D printing increases with firm size. Furthermore, industrial automation is associated with a larger productivity gap between large and small firms. This reflects the fact that, similar to other physical capital, implementing a robot or additive manufacturing application entails large fixed costs, which is likely to benefit larger enterprises.

Industrial automation has not lowered aggregate employment, but workers will face adjustment costs and there are inequality concerns as the labor share in value added falls. Recent estimates, which combine the negative displacement and positive productivity effects of industrial robots on jobs, range from a mild negative to a positive aggregate impact. At the same time, the use of industrial robots has changed the composition of employment in terms of sectors, tasks and skills. Industrial automation has also resulted in a declining labor share of value added, including when changing sectoral compositions are considered. Therefore, while labor displacement in certain tasks and industries can eventually be counteracted, there will be adjustment costs in the short run, and the gap between workers and owners of capital could widen over the long run.

Industrial automation in European HICs has reduced offshoring to lower-wage countries in the region. This indicates that smaller more recent EU-13 countries, such as the Czech Republic, the Slovak Republic and Slovenia, are perhaps not automating enough to compensate for rising wages relative to Asia. Within countries, clustering in the use of industrial robots reflects the existing geography of manufacturing hubs and will therefore reinforce existing patterns in the spatial distribution of economic activity. There is also a clustering of countries and regions within countries with regard to the ability to create new operational technology applications, as measured by patents. Germany stands out among countries in Europe. Within countries, robotics developers and suppliers concentrate in locations known for being knowledge and innovation hubs.

## Notes

1. This means that while initial investment in advanced robotics may be significant, there may be less need to keep purchasing additional machinery over time. Advanced robotics may add between US\$1.7 and US\$4.5 trillion to global GDP per year until 2025 (UNIDO, 2016; Manyika, 2013).
2. The process of creating functional prototypes from plastic resin for R&D and product testing purposes.
3. The fact that Germany has the highest intensity of robot use worldwide but not the highest share of manufacturing firms that used robots may be explained by the concentration in its use among a few leading automotive producers (European Commission, 2016).
4. This comprises commercially deployed M2M services and therefore excludes computing devices in consumer electronics such as e-readers, smartphones, dongles and tablets.
5. Defined by the interviewer (if necessary) as: “electronic devices that communicate with each other without human assistance” (EBIS questionnaire, 2019).
6. Adoption rates may be higher in certain industries. Based on survey data from 124 medium and large automotive manufacturers across 17 countries in Europe (the majority of responses were from firms in Croatia, France, Italy, Germany and the United Kingdom), Delic et al. (2019) find that more than 60 percent of the respondents indicated that their firms have adopted 3D printing.
7. This information is based on IFR 2016 data and while the authors state that there are 12 countries and 28 suppliers, they only mention these countries with the corresponding number of suppliers.
8. There are 500 companies in the German robotics industry and most of these companies are lead suppliers and OEMs (Estolatan et al., 2018).
9. Advances made by European firms to address key safety and payload issues highlight the region’s potential.
10. The authors also estimate that B2B ecommerce can be five to six times as large as B2C ecommerce.
11. After acquiring GN ReSound.
12. Respondents were from 17 countries in Europe. The majority of responses were from firms in Croatia, France, Italy, Germany and the United Kingdom.
13. This controls for country- and industry-specific factors.
14. The positive impact of robotization in the North on imports from the South is mainly driven by exchanges of parts and components.
15. The extent to which productivity growth creates jobs and raises incomes will depend on the responsiveness of demand to changing prices and incomes. Over the very long run, gains in productivity have not led to a shortfall in demand as household consumption has largely kept pace with household incomes (Lawrence, 2017; Autor, 2015).
16. The number of tellers per branch fell by more than a third between 1988 and 2004, but the number of urban bank branches increased by more than 40 percent (Bessen, 2016).
17. Increasingly, banks recognized the value of tellers, not primarily as checkout clerks, but as salespersons, forging relationships with customers and introducing them to additional bank services like credit cards, loans, and investment products (Acemoglu and Restrepo, 2018).
18. Raj and Seamans (2019) highlight the fact that direct comparison across studies is complicated by the use of different units of analysis (i.e., tasks, occupations, specific sectors, country-level).
19. The authors define automation as: “costs of third-party automation services”. Examples include the purchases of new software releases and robotics integrator services.
20. All Western European countries except for Australia, Japan, Republic of Korea, and the United States.
21. For example, auto-intense metro Detroit—with more than 15,000 industrial robots in place or 8.5 per 1,000 workers—dominates the map with more than three times the number of installed robots of other metros. Several smaller towns and cities in the Midwest and South are also heavily involved with robots, with robot densities higher than any larger metro (16.6 robots per 1,000 workers in Morristown, Tennessee to 35.2 and 25.9 in Kokomo and Elkhart, Indiana).
22. The ability of regions to develop new operational technologies, as measured by patents, depends on capabilities related to their existing technological specializations. Countries and regions are more likely to develop new activities related to their existing activities. This principle of relatedness can be used to identify the potential of regions to develop operational technologies (Boschma, 2017; Hidalgo et al., 2018).

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# ANNEX 5

**TABLE A5.1** Relationship between operational technologies and labor productivity, firm Level, 2019

	<b>3D Printing</b>	<b>Advanced Robotics</b>	<b>IoT</b>
Digital Technology	0.11** (0.05)	0.13** (0.06)	0.03 (0.04)
	Reference Sector	Only Sector	Reference Sector
Sector			
Manufacturing	Reference Sector	Only Sector	Reference Sector
Construction	-0.03 (0.04)	N/A	-0.04 (0.04)
Services	N/A	N/A	-0.32*** (0.04)
Infrastructure	0.04 (0.04)	N/A	0.03 (0.04)
R-Squared	0.19	0.24	0.17
N	7713	3157	10192

Source: Cathles, Nayyar and Rückert (2020), using data from the 2019 EIBIS Survey.

Note: The dependent variable is log of labor productivity. The constant and country dummies are included, but not reported. Firms in different sectors were asked about different digital technologies, N/A indicates when a sector was not asked about a particular technology. The reference sector is also indicated. Firms in EIBIS are weighted with value added. All countries in the EU-28 and the United States are included in the regressions. Robust standard errors in parentheses.

\* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

**TABLE A5.2** Relationship between operational technologies and employment growth, firm level, 2019

	<b>3D Printing</b>			<b>Robotics</b>			<b>IoT</b>		
Digital adoption	0.13 (0.14)	-0.06 (0.15)	0.05 (0.17)	0.12 (0.15)	-0.04 (0.17)	0.15 (0.18)	0.51*** (-0.09)	0.42*** (-0.09)	0.34*** (-0.1)
Manufacturing	Reference	Reference	Reference	Only	Only	Only	Reference	Reference	Reference
Construction	0.06 (0.11)	0.38*** (0.13)	0.42*** (0.15)				0.1 (-0.11)	0.40*** (-0.13)	0.44*** (-0.15)
Services	N/A	N/A	N/A				-0.23** (-0.1)	0.02 (-0.12)	0.19 (-0.13)
Infrastructure	-0.02 (0.1)	0.15 (0.12)	0.17 (0.13)				-0.03 (-0.1)	0.16 (-0.12)	0.14 (-0.13)
Micro		Reference	Reference		Reference	Reference	Reference	Reference	Reference
Small		0.79*** (0.12)	0.73*** (0.14)		0.73***	0.49*		0.84*** (-0.09)	0.85*** (-0.11)
Medium		1.09*** (0.12)	1.00*** (0.15)		1.13***	0.82***		1.08*** (-0.1)	1.04*** (-0.12)
Large		1.19*** (0.14)	1.00*** (0.17)		0.95*** (0.25)	0.59* (0.3)		1.15*** (-0.11)	1.10*** (-0.14)

	3D Printing			Robotics		IoT		
	Reference	Reference		Reference	Reference	Reference	Reference	Reference
Less than 5 years								
5 years to less than 10 years	0.04 (0.36)	-0.38 (0.36)		-0.08 (0.49)	-0.29 (0.56)		-0.1 (-0.28)	-0.41 (-0.29)
10 years to less than 20 years	0.16 (0.33)	-0.11 (0.32)		-0.18 (0.46)	-0.1 (0.52)		0.04 (-0.25)	-0.12 (-0.25)
20 years or more	-0.28 (0.32)	-0.55* (0.31)		-0.42 (0.42)	-0.54 (0.48)		-0.34 (-0.24)	-0.51** (-0.23)
Exporter	0.25** (0.12)	0.29** (0.13)		0.13 (0.21)	0.18 (0.24)		0.21** (-0.1)	0.26** (-0.11)
Innovator	0.41*** (0.11)			0.41*** (0.16)			0.37*** (-0.09)	
Basic		Reference			Reference			Reference
Adopting		0.14 (0.22)			0.36 (0.35)			0.18 (-0.19)
Incremental Innovators		0.61*** (0.17)			0.77*** (0.25)			0.50*** (-0.14)
Leading Innovators		0.35* (0.2)			0.33 (0.28)			0.34* (-0.18)
Developers		0.34** (0.15)			0.36 (0.25)			0.32** (-0.13)
N	9183	8915	6814	3613	2818	12216	11837	8946
Pseudo r2	0.01	0.04	0.03	0.03	0.05	0.07	0.02	0.04

Source: Cathles, Nayyar and Rückert (2020), using data from the 2019 EIBIS Survey.

Note: The dependent variable logit is increase in employment compared to 3 years ago = 1, and otherwise = 0. The constant and country dummies are included, but not reported. Firms in different sectors were asked about different digital technologies, N/A indicates when a sector was not asked about a particular technology. The reference sector is also indicated. Firms in EIBIS are weighted with value added. All countries in the EU-28 and the United States are included in the regressions. Robust standard errors in parentheses.

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$  –



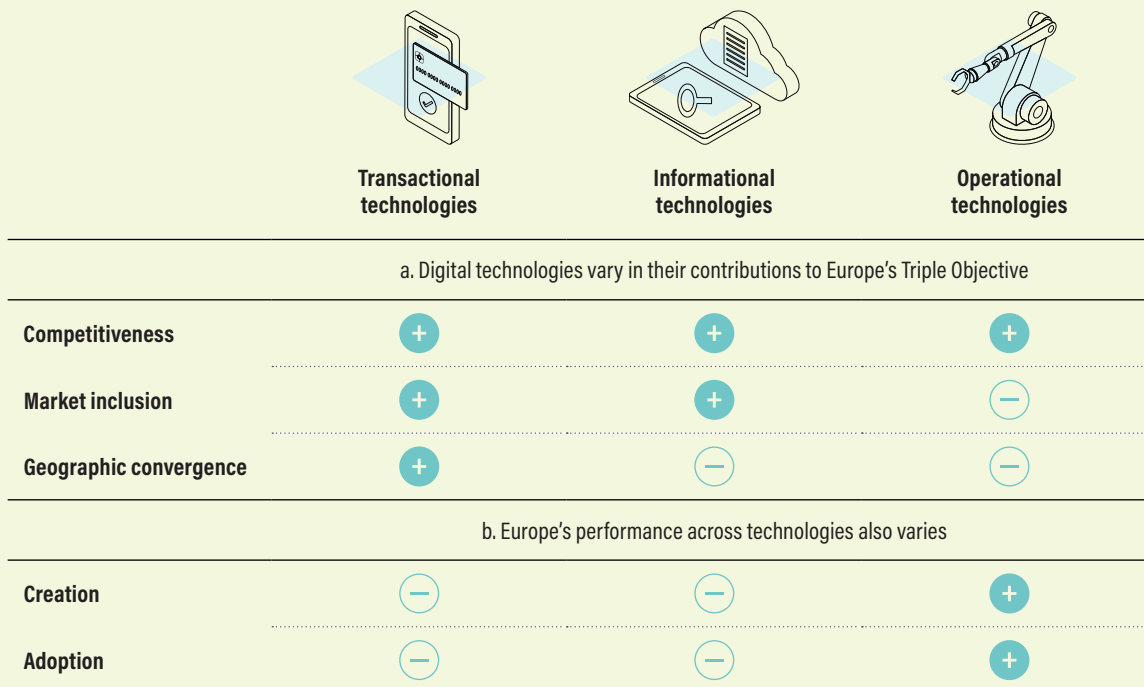
## CONCLUSION TO PART II

The empirical evidence presented here confirms the importance of not treating technology as a monolithic force for change. The dynamics vary across transactional, informational and operational technologies.

Taken together, these findings show that Europe faces a digital dilemma. In those technologies where the potential for inclusion and convergence is greatest, European firms are not so competitive. Where European firms are competitive, new opportunities are more concentrated in larger firms and leading regions.

However, distinguishing across types of technology also highlights the pathway to achieve Europe's three goals by identifying where there are synergies and ways to manage trade-offs. If Europe wants to achieve its three goals, any policy response must take into account these differences.

**FIGURE C2.1** Europe faces a Digital Dilemma between its objectives and its performance



Source: Europe 4.0 team.

# PART III



CHAPTER 6:  
**Transactional Technologies:  
Scaling Up Markets  
to Better Realize the Potential  
for Europe's Triple Objectives**


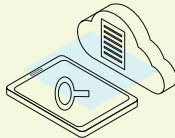
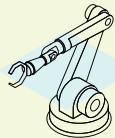
CHAPTER 7:  
**Informational Technologies:  
Shaping Regulations  
for Innovation and Inclusion**

CHAPTER 8:  
**Operational Technologies:  
Smoothing the Diffusion  
of Technology for Greater Inclusion  
and Convergence**

## INTRODUCTION TO PART III

Part III of this report discusses the policy priorities in addressing the digital dilemma. Given that the technologies vary in their relative contributions to each of the three goals, policymakers need to differentiate their approaches by technology. Thus, this section devotes one chapter to a discussion of the priorities for each of the three technologies, and how policies can address the underlying drivers associated with each technology in ways that can help strengthen its overall contributions. The focus is on mitigating any tensions that might be generated between Europe’s three goals or on reinforcing potential strengths that are not being fully realized. Taken together, the agenda makes clear how Europe 4.0 can be achieved, and how new digital technologies can contribute toward competitiveness, inclusion and convergence.

**FIGURE I3.1** Addressing the Digital Dilemma

	 <b>Transactional technologies</b>	 <b>Informational technologies</b>	 <b>Operational technologies</b>
<b>Digital dilemmas</b>	Contributes to all three goals, but limited competitiveness means that potential is only partially realized	European firms show more promise, but new opportunities are more concentrated	European firms are among leaders, but technologies favor large firms and increasingly concentrate production
<b>Policy directions</b>	Scaling markets	Shaping commercial use of data	Smoothing adoption in MSMEs and lagging regions

Source: Europe 4.0 team.

For transactional technologies, scale is a key feature in meeting the network effects needed to serve both sides of the market, i.e., consumers and sellers on the digital platforms. Constraints to achieving scale are thus the priority for this technology. For businesses built on informational technologies, access to data is key. So, scale matters here too, but so do the regulations that shape how data can and cannot be used. Rules on data privacy and data sharing are critical. Rules around competition and how digital businesses use their scale and position are important too. For operational technologies, while data intensive, the network effects are less pronounced, so the emphasis on scale is relatively less important. The concern is more that the skill requirements and capital intensity serve to favor larger firms and existing production hubs. Doing more to support the diffusion and adoption of technology is important here, and B2B tools and expanding applications of AI could help more smaller firms and new entrants across a wider range of locations to become looped into value chains.

It should be noted that many of the recommendations will benefit the creation and diffusion of all three of the digital technologies. However, the relative importance of the policy areas is not equal across technologies. They are matched only to the extent to which they address the underlying economic dynamics that the technology presents and thus the policy's contributions to addressing that technology's contribution to the digital dilemma.

The recommendations are discussed at both the levels of the EU and national governments. There are several priority regulatory issues at the EU level that address fundamental incentives and abilities to expand the take-up of each technology. For non-member states, these issues will be relevant for national governments, but only to the extent that they address the need for scale and harmonization. Looking at how best to be aligned or compatible with EU regulations should be an important consideration here. For all national governments, priorities not only include putting regulations into practice, but also directly supporting more firms to adopt and use new technology through public investments and targeted programs.

Three broader policy debates emerge from the discussion. The first regards the scope of the agenda. Is the agenda one that is focused on technology policy, or do many of the traditional or 'analog complements' need attention too? This is particularly relevant for transactional technologies that use digital business models to deliver goods and, increasingly, services. To support the expansion of transactional technologies, this will require policies to address the bottlenecks that occur due to the limitations of the single market and on the 'last mile' complements that enable physical transactions to be completed (e.g., logistics). These issues are discussed in Chapter 6.

A second debate is around champions, and the question of whether Europe needs to have digital champions of its own. With a growing recognition of the role of data and AI, this debate often centers on whether Europe needs to be self-reliant on how data are processed and used, from cloud computing to the new ways that AI can be developed and deployed. This then dovetails with the discussions on shaping the regulations around data, and whether these regulations are made in order to foster champions or not. How 'competitiveness' is understood is central, with major implications for the compatibility of Europe's three goals. This is discussed in Chapter 7.

A third debate is whether it is possible to catch up, let alone leapfrog, naturally, or whether policies and public investments are also needed to help certain locations and specific firms to adopt technologies. This has important implications for how resources are allocated, whether to focus on moving out the frontier or assisting with the diffusion of technologies so that more firms can raise their productivity. This is discussed in Chapter 8.

Answers to these three strategic debates then shape priorities across the three goals and the types of policies within them. Each chapter looks at what is at stake in the debate and provides concrete recommendations on how to move forward.



## CHAPTER 6

# TRANSACTIONAL TECHNOLOGIES: SCALING UP MARKETS TO BETTER REALIZE THE POTENTIAL FOR EUROPE'S TRIPLE OBJECTIVES

Transactional technologies can contribute to all three goals—raising the productivity of firms that use them, expanding access to markets for smaller firms, and expanding access for firms in more remote locations. The issue for Europe is the relatively low level of uptake of transactional technologies, together with the relative lack of European firms among the global leaders in this technology. The surge in demand for transactional technology-driven businesses in the wake of the COVID-19 crisis further underscores the importance of expanding the use of this technology.

Understanding the underlying sources of this lack of competitiveness is critical to expand the offerings and use of these technologies. Too often the agenda and recommendations get caught up in different debates over what ‘competitiveness’ means (Box 6.1), including whether the focus should be on larger firms—or on larger markets.

The source of efficiency gains from transactional technologies is the improved ability to match supply and demand. This depends on scale, on having sufficient numbers of users on both sides of the market that the transactional platforms are trying to match. Exploiting network effects is what allows these technologies to take off and become successful; without larger markets it will be hard to achieve larger firms in transactional (or informational) technologies. Thus, restrictions on market size—either from regulatory barriers or other practical constraints on being able to reach potential users, or to deliver goods and services—will be of first order concern for these technologies.

## BOX: 6.1 Competing views of “competitiveness”: Does Europe need larger champions or larger markets?

Tech giants grab headlines — and policymakers’ attention. The fact that the biggest tech firms are U.S. and Chinese raises questions as to why more have not grown up in Europe and whether more needs to be done to create European champions. Beyond a sense of pride in having large firms, it is worth unpacking what the issues are — not just in static terms but in dynamic ones. Three arguments as to why global players or champions may be needed are considered. Each has implications for the appropriate policy response.

The most convincing cases appeal to externalities, that the value of the giant is not just that it is big, but that as a big player it can catalyze or anchor growth of an ecosystem of firms, expanding opportunities to other European firms. Most of these arguments are focused on informational and transactional technologies, but they have implications for the positioning of Europe’s operational technologies too.

### Case 1: Europe as a source of global innovators and standard setters

The first case is about making European firms relevant globally, having them be on the cutting edge. The assumption is that these firms would be that much more profitable and larger employers. To the extent they anchor supply chains that could expand opportunities for other European firms, they would also contribute to the other goals of inclusion and convergence.

### Case 2: GDPR as a source of comparative advantage and wider influence on global values

A second case centers on a key dimension of ‘European-ness’ and what standards the leading firms are likely to set. Europe has a deeper commitment to value- or mission-based manifest most clearly on issues of data privacy and on issues of sustainability. A European data technology giant would ensure alignment of the leading firms with societal values in ways that could have global influence. If such data privacy and environmental standards can themselves be demonstrated to be a source of comparative advantage, it could have dynamic benefits for the whole ecosystem of European firms. Based on this view, GDPR is not something that may be slowing down Europe’s innovation and growth potential, as is sometimes argued by its critics, but instead it is the best way for these values to become that much more dominant.

### Case 3: Technological sovereignty

A third case takes a different reasoning. Rather than building on Europe’s strengths, the concern is about avoiding potential weaknesses. Technological sovereignty is about having Europe’s own technology giants to ensure the viability of its economic and strategic interests. The argument is that certain technological infrastructure or services are of such strategic value that relying on other countries to provide them is too risky. With Brexit, new uncertainty over trade relations with the United States, and the potential decoupling of U.S. and Chinese technology markets over security concerns, this debate has been receiving increased attention.

### Whatever the type of champion, how it would emerge also matters

Even if the objective of having champions is accepted, there are still questions on how to achieve it. The policy implications of these three

cases are different. With the first lens, to encourage more frontier firms would mean addressing the enabling conditions for scale and a greater emphasis on supporting innovation (Chapter 6). The second would look at how to address concerns that data regulations are inhibiting rather than providing a safer space for innovation, that trust in the goals and processes of innovation are themselves a strength. It would call for both enforcement of privacy standards, while pushing forward more safeguarded ways to share data for human-centric purposes (Chapter 7). Technological sovereignty argues that having certain types of European giants are not just desirable, but necessary. If such European services will not develop at scale on their own, a more active response from governments is needed — for R&D but also for complementary infrastructure and other services (Chapters 6 and 8).

### Larger markets rather than champions

There are certainly important insights that come from these debates. But they also miss the bigger picture. If having a champion is the measure of success, it places the whole focus on just a narrow part of the productivity agenda. Emphasizing size may be even be misleading, particularly for technologies that do not have the same network effects as some informational or transactional technologies. The focus on global champions points to Europe’s gap in these informational and transactional technologies, but disguises Europe’s success in operational technologies — or ways that industrial technologies can build on information and B2B platforms to be cutting edge, even without quite the same scale effects. These technologies add value, spur innovation and provide dynamic gains for suppliers, even if they are not in the top 10 global firms.

Given Europe’s triple imperatives, this focus on champions risks diverting attention and resources away from Europe’s broader goals—unless that is the case for positive spillovers can convincingly be made and concerns of distortions from top-down approaches can be assuaged. To achieve Europe 4.0 the measure of competitiveness should not just be on whether there are global champions per se, but on whether there are incentives to realize dynamic gains, of supporting a healthy ecosystem that is innovative and productive and making new, societally desirable, opportunities available.

Shifting from the narrow understanding of competitiveness from the size of the dominant players to the efficiency and productivity of the ecosystem may well provide positive feedback loops that support the frontier firms. A vibrant ecosystem encourages entry, innovation, growth, and the exit of unproductive firms. This does not only involve support to innovation and pushing out the frontier, but importantly diffusion. It also places more focus on addressing the underlying constraints on developing Europe’s digital markets, including the continued fragmentation of the digital Single Market and on the ecosystem for startups. To achieve Europe 4.0, to embrace new digital technologies to achieve greater competitiveness, inclusion and convergence, the emphasis should be on strengthening larger and well-regulated digital markets, not champions.

At the level of the European Union, the agenda is about completing the digital single market (DSM) to allow safeguarded data and digital services to flow within Europe. It is also about tackling remaining restrictions on the trade in services, particularly those that can be delivered digitally. At the national level, there are



three dimensions to the agenda. The first is implementing the single market regulatory framework to facilitate the movement of goods, services, capital and people that transactional technologies seek to match within and across borders in Europe; the second is supporting infrastructure and logistics to enable the use of digital technologies to deliver goods and in-person services; and the third, where informal transactions are relatively common, address governance issues that affect the incentives to use platforms that have digital footprints of transactions. These last issues can be relevant at the subnational level too.

One key lesson is that the scope of this agenda is whether the agenda should not be narrowly construed as primarily a ‘technology agenda’; complementary policies and investments are needed too. This chapter argues that much remains to be done to complete the agenda for the third industrial revolution, making it possible to access and use ICT. The uneven take-up of a technology that is not that costly or skills intensive also reinforces the issue that the use of new technologies is not automatic, and that access to broadband on its own is not sufficient. The agenda is not only about digital technology policies; the ‘analog complements’ that make it possible to access and use data-driven technologies determine how widespread the use of these technologies will be, and thus the extent of productivity gains, and the extent of inclusion and convergence in access to new opportunities. The COVID-19 pandemic reinforces the importance of this agenda; transactional technologies are providing key ways to enable more economic activities to occur—and occur more safely in the current environment (Box 6.2).

**BOX 6.2** The promise of transactional technologies when face-to-face interactions become an occupational hazard, as during the COVID-19 pandemic

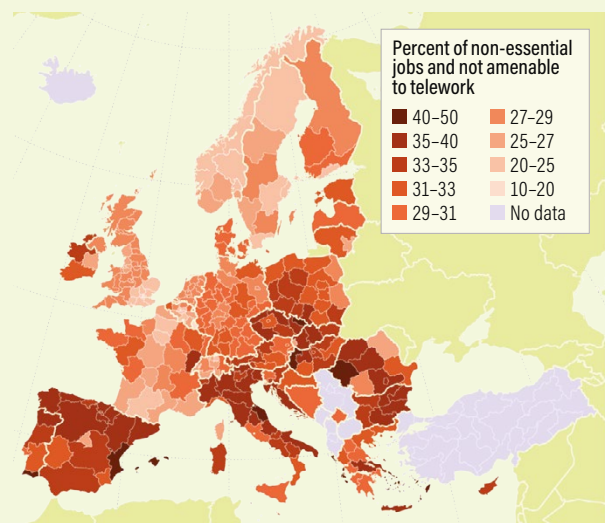
There is a crisis of demand brewing around the globe as social distancing becomes the norm to counter the COVID-19 pandemic outbreak. Examples abound of job cuts as authorities ask restaurants and bars to close, while manufacturing activity in global value chains is increasingly disrupted too. So, which parts of the economy are most in the line of fire? In the short run, the possibility to do home-based work is what matters for immediate job losses during the lockdown (Dingel and Neiman 2020). However, as restrictions are lifted, activities intensive in face-to-face interactions may well be slower to recover, with consumers remaining apprehensive and more safety conscious than before (Avdiu and Nayyar 2020).

Estimates suggest that the share of jobs that cannot be performed from home in non-essential industries accounts for 30 percent of employment in the EU (World Bank 2020). Furthermore, European regions with lower levels of per capita income have a lower share of jobs that are amenable to home-based work. The ratio is between one-third to half of all jobs in large parts of Southern (Portugal, Spain, Italy, Greece) and Eastern (Romania, Czech Republic, Hungary, Slovakia) Europe. The share of jobs that can be performed from home is significantly higher in Scandinavia, France, Germany and the United Kingdom (see Figure below). This pattern is qualitatively similar when vulnerability is measured by the importance of face-to-face interactions with consumers. The main exceptions are Central and Eastern European countries, such as the Czech Republic, Hungary and Slovakia, which are less exposed owing to a higher share of manufacturing jobs that cannot be done from home, but that also do not involve much face-to-face interaction with consumers.

The use of digital platforms, by facilitating online ordering and home delivery, has been a lifeline for food services and the retail trade, which are not amenable to home-based work and unsurprisingly the most intensive in terms of face-to-face interactions with consumers. Elsewhere, these platforms have made activities that are typically intensive

in face-to-face interactions more amenable to home-based work by enabling digital delivery. For example, high school teachers can provide lectures through online platforms such as Zoom, Microsoft teams and Skype, even if the teaching quality might be lower than interactive sessions in the classroom. Similarly, managers in companies can liaise with staff on these digital platforms, even if their ability to effectively supervise and coordinate tasks is somewhat inhibited (Avdiu and Nayyar 2020).

**MAP B6.2.1** The ability for transactional technologies to support economic activities during the COVID-19 pandemic varies significantly across Europe



Source: World Bank 2020.

# SCALING-UP: ADDRESSING FRAGMENTATION IN EUROPEAN MARKETS

It is hard to achieve scale when serving fragmented markets. This is particularly true for digital business models, where scale is critical. That the United States or China have large internal markets is certainly part of the reason why their data-intensive tech companies are so large, whereas Europe's nascent DSM still has digital, and analog, barriers that keep it fragmented. Addressing the remaining barriers to the single market, particularly the digital single market, needs to be prioritized to achieve more competitive markets. For non-member states, this involves expanding digital trade with the larger EU market.

In theory, transactional (and informational) technologies should make geography matter less. However, Chapter 3 (and also Chapter 4) shows that strong geographical differences in the use of digital technologies remain prevalent. While the use of ICT and data has certainly diminished the importance of geography and distance, it has not made the “world flat” (Grillo et al. 2015). While transactional and informational technologies should be making it easier to connect digitally to larger markets anywhere in Europe—or around the world—there are limits. The lack of convergence in e-commerce and e-government shows that the agenda includes, but also goes well beyond, simply having access to broadband. It includes the availability of supporting logistics infrastructure and other ‘analogue complements’, such as the quality of governance and regulatory enforcement, as well as the skills needed to make the use of technology viable in a region.

Despite the EU's best efforts, Europe is home to a well-documented digital divide. Northern Europe and most of the EU-14 (with the exception of Greece, Italy and Portugal) lead Central and Eastern Europe in both digital technology creation and adoption. While much progress has been made in expanding broadband coverage and ICT access, lagging regions have generally struggled to catch up in digitization and productivity with leading European economies.

The European digital divide is strongly influenced by national boundaries. Evidence shows that access to ICT infrastructure is not enough to explain the disparities that persist across member states. Recent findings are mixed, but studies agree that national borders (and, by implication, national policies and institutions) are a clear determinant of digital adoption. Other identified factors include the availability of digital skills, the quality of logistics infrastructure, and the quality of government (Rodriguez-Pose and Ketterer [2018]; Annoni and Catalina-Rubianes [2016]; Crespo et al. [2019]).

As previewed in Chapter 1, the limited use of e-commerce underscores the untapped potential for transactional technologies more broadly. According to Eurostat data, in 2018, only 16 percent of EU consumers bought online from traders based in other member states. From the firms' perspective, it is even lower: 10 percent of online sales for EU companies come from other EU countries. In 2016, fewer than 37 percent of e-commerce websites even allowed for cross-border purchases. The continued use of geo-blocking and restrictions on parcel deliveries are of the greatest concern for consumers in smaller and less central countries; smaller demand in these countries make them less attractive for foreign companies to service and the relative costs of delivery are likely to be higher. Sellers can refuse to sell to purchasers in another country if they do not regularly deliver in that location (see Box 6.3).

## **BOX 6.3** The Amazon paradox: Why does it cost more and take longer for e-commerce across countries in Europe?

There remain important constraints to e-commerce in the EU, in part due to digital barriers, but even more so because of constraints in other services that underlie e-commerce, in particular postal delivery services. Distances in the United States are longer, yet package delivery is faster—and often considerably cheaper.

The Geo-Blocking Regulation (EU) 2018/302 put an end to unjustified geo-blocking on many sites; e-commerce sites in the EU are no longer allowed to block visitors from other countries. However, while sites do have to offer to sell to all countries, they do not have to deliver to customers' homes. Only 37 percent of e-commerce sites offer to deliver

across national borders within Europe. Restrictions on copyright also make certain goods and services non-portable.

But non-digital restrictions matter too. The most important explanation lies in the continued fragmentation of postal delivery services. In many countries, these are state-owned and, while there are no formal restrictions on entry, there is little way to compete against state-sponsored and funded services. There are also some countries that require all postal packages to go through central hubs, so even if an e-retailer is close to the customer, packages may need to travel long distances

Source: Van Der Marel 2019.

through these hubs rather than be delivered directly. For example, even for cross-border destinations as close as 10 km away, such as from the Netherlands to Belgium, parcels still need to be loaded from the regional depot to the national sort hubs before being sent later for delivery (University of Antwerp 2015).

And prices vary considerably too. The differential price in package delivery is equal to a factor of 3.71. This comes down to an average price difference of 471 percent for packages sent to another country in the EU compared with packages that are sent domestically.

## EU LEVEL: REALIZING THE POTENTIAL OF EUROPE'S DIGITAL SINGLE MARKET

### Completing the digital single market

#### What is at stake?

The European Commission in 2015 identified €177 billion in potential annual economic gains from the full implementation of its Digital Single Market Strategy. The largest gains were seen as coming from: (i) improved electronic communications networks and services; (ii) data and AI, based mainly on a directive on the re-use of public sector information, and secondly on the free flow of non/personal data; (iii) e-commerce, content and online platforms, based on the Geo-Blocking Regulation, the VAT modernization program, and the Regulation on Cross-Border Parcel Delivery; and (iv) e-government, provided that the Single Digital Gateway is implemented well and widely used. This is in addition to improved efficiency gains from individuals and businesses seamlessly accessing and exercising online activities (EP 2016 study).

At the end of the Juncker presidency, 28 of the 30 proposed initiatives of the DSM had been agreed to. These initiatives do indeed move the EU closer to completing the DSM, but several are partial steps. On geo-blocking, sites cannot be blocked based on the location or nationality of the users and users from across the EU can all make purchases on e-commerce sites. However, the sellers are not required to deliver across borders, or even outside their narrower jurisdiction. This makes sense for perishable items, but not for durable goods. Regarding cross-border parcel delivery, the reform largely tackles pricing transparency and strengthens the ability of regulators to monitor the sector, but it does not address the challenges of working with multiple national systems, each with its own procedures, timing and costs. The Evaluation of the Postal Services Directive, initiated in early 2020, will examine competition in the EU and national postal markets, and assess whether the current regulatory instruments are flexible enough to accommodate national particularities.

The legislative progress that has been achieved on many of these agenda items has yet to be translated into significant changes on the ground. With some having just come into force, it is naturally too soon to see their impacts in the data. Monitoring their effective implementation and the impacts on addressing costs and constraints in realizing the DSM will be important. Issues of data localization are one such example where the reforms are now being enacted, but it is still too early to determine their impact in practice (see Box 6.4) and also on several important analog complements.

#### BOX 6.4 Data need to flow to support transactional technologies

Since Europe depends more than other regions on the trade in services, obstacles to the movement of data are especially harmful in Europe. Cross-border information flows are the fastest growing component of trade in both the EU and the United States. Even back in 2008–12, data flows increased by nearly 50 percent, while the trade in goods and services grew by less than 2.5 percent (Mandel 2014). This pace is likely to have picked up over the past eight years. Whereas China accounted for 13 percent of global data in 2012, it overtook the United States in 2016, and is estimated to be on track to generate and store almost 30 percent of all the data in the world by 2025 (Reinsel et al. 2020).

The diagnosis points to market fragmentation as the underlying cause of this problem. The EU market is comparable to China's and the US economy, but it is not nearly as integrated. And 'data localization' regulations in EU member states compound this, acting like a non-tariff barrier to trade. Examples of such regulations include Luxembourg's financial supervision requirement that client data be stored and processed locally; rules in Germany that all accounts be stored in the country; corporate bookkeeping rules in Belgium, Finland, Sweden and the United Kingdom that financial records be stored domestically; the Danish Book Keeping Act that requires that corporate financial records be stored in Denmark or in one of the Nordic countries; general stipulations on publicly held records in Denmark, the Netherlands, Sweden and the United Kingdom; and France's amended Code of Electronic Communications

that includes a 'territorial restriction' that the electronic communications systems must be installed and all data processed in France.

Many member states also have data retention requirements that persist despite being ruled invalid by the European Court of Justice (European Commission 2017). Regulation (EU) 2018/1807 on the free flow of non-personal data, applicable as of May 28, 2019, bans data localization requirements in EU member states, unless justified on the grounds of public security. Member states have a two-year grace period to eliminate existing data localization requirements, or to notify the Commission if they deem any of these requirements necessary for public security. This important issue is thus being addressed, but there remains time before the regulation fully comes into effect, and it is too soon to know how many exceptions will be sought.

As a result of these data regulations, two-thirds of ICT-related services are sourced domestically, and just 18 percent are sourced from other parts of the EU (Bauer et al. 2016). Of the top 25 public cloud service providers active in the EU market, 17 are headquartered in the United States and collectively generate 83 percent of revenues. Seven EU-based providers account for 14 percent of the revenues (European Commission 2017, page 8). Data localization statutes are also estimated to reduce data-related investments in the EU by 4 percent, compared with 2 percent in China and 1.5 percent in India (Bauer et al. 2014).

Source: Authors.

The new von der Leyen presidency is building on the legislative achievements to date and launching a new ambitious phase to this agenda. Its vision is pressing forward the scope of what the DSM would entail. It is putting forward more concrete proposals for the 'shared data space' for Europe, which could be included in a new Data Act. The vision is that these European data spaces, covering strategic sectors, create conducive regulatory frameworks and data governance systems that allow for data to flow within the EU and across sectors, while ensuring that European values and rules related to privacy, consumer protection and competition law are adhered to. These new proposals are motivated to a significant degree by raising the competitiveness of European firms in the digital economy—and ensuring that SMEs have access to these opportunities. Data spaces are expected to foster new products and services based on more accessible data. How data regulations can shape how inclusive this approach is likely to be is discussed in Chapter 7.

#### What to do?

Thus, there are two outstanding priority issues to complete the DSM, but also multiple additional areas both at the EU and national levels to make the DSM work in practice, from addressing broader restrictions in the trade in services, and addressing differences in regulatory approaches and standards in the implementation of the DSM in practice. The digital issues are discussed here, and the others in the subsections below.

On direct measures to realize the DSM, the remaining issues of geo-blocking need to be addressed. Individuals and firms need to be able to access online services, regardless of where they are in Europe. Currently, websites can be accessed, but there are practical limitations on being able to use them. Some of this relates to issues of delivery across jurisdictions; online sellers do not have to deliver to other jurisdictions. It also relates to restrictions on the use of digital payments or credit cards across national boundaries. To be effective, this also requires addressing the remaining issues in harmonizing requirements related to product safety and labeling, and the mutual recognition of goods sold in another member state.

Second, there remain issues with portability and copyright, including of digital creative content. There are questions on the vertical agreements in the distribution of audiovisual content and barriers to cross-border accessibility to digital content. A new Portability Regulation came into effect in April 2018 to address these issues, but the regulation lacks any enforcement mechanisms and does not regulate several practices that could hinder portability, such as constant checking of IP addresses to monitor consumers' whereabouts, or limiting the range of devices on which portability is available.

## Realizing the single market in services

### What is at stake?

Regulatory policy barriers in services typically affect either the entry of firms into a market or the operations of incumbent firms. Evidence indicates that the rate of firm entry in the EU is not substantially different from that of the United States (Bertelsman et al. 2003). What is different, however, is that firms in the EU are less likely to expand quickly once they have entered and have greater difficulties in pushing out less-productive firms from the market (OECD 2015). A recent study by Van der Marel et al. (2016), using data from millions of European firms, also shows that the removal of operational restrictions is what matters for productivity growth in services markets.

Nonetheless, barriers on market entry for foreign (and domestic) firms remain important in certain sectors, especially road transportation and professional services such as engineering, and legal, accounting and architectural services (Van der Marel 2017). These restrictions ultimately reduce consumer choice and the positive effects of a truly single European services market. In fact, professional services have seen negative productivity growth in recent years, underlying the fact that competitive forces remain untapped. This has also had a knock-on effect on productivity in other sectors too (Arnold et al. 2011; Van der Marel et al. 2016).

It is also important to distinguish between services trade restrictiveness within the single market comprising EU and EEA members, relative to trade barriers with respect to third countries. Taking into account EU rules and national laws in a services trade restrictiveness index (STRI), OECD (2019) finds that distribution, logistics cargo-handling, and rail freight transport are characterized by the highest average intra-European Economic Area (EEA) STRI relative to the average MFN STRI across all EEA members. Barriers to competition can represent a substantial impediment to trade in distribution services within the EEA. In several member states, competition in the retail sector is affected by an upper limit on shop opening hours, the regulation of seasonal sales periods, and specific taxes. In a majority of EEA members, barriers to competition in the logistics cargo-handling sectors are affected by the presence of state-owned companies (Van der Marel 2017).

The ability to deliver services digitally should open access to new opportunities, particularly for SMEs. Recent empirical analysis shows that average services trade restrictions are equivalent to up to a 14 percent additional tariff on small firms' exports compared with large firms that can absorb trade costs more easily.

The response to the COVID-19 pandemic and the shift toward more online work has shown the enormous upside potential of expanding the use of transactional technologies — to enable both more and safer transactions. E-commerce has seen dramatic increases, but so too has the potential for the delivery of professional services, where the earlier reluctance to move to virtual provision has been swiftly overcome, for example in telemedicine or remote learning. The potential for greater trade in many services is thus being demonstrated. The question for Europe is to what degree the existing constraints to realizing this potential will be addressed.

### What to do?

In general, the services trade within the EEA became more liberal between 2014 and 2019. This was partly driven by new EU rules, such as the GDPR, but also by domestic policy reforms. The 'Services Package' is a set of measures that aims to make it easier for firms to start and expand, particularly in professional services such



as legal, accountancy and engineering. One instrument is the proportionality test for (professional) services, which assesses whether new legislations and changes to existing rules are either overly burdensome or outdated. For professional services, this test should therefore specifically focus on barriers to entry for outsiders willing to come into the market (Van der Marel 2017).

Directive 2013/55/EC promotes automatic recognition of professional qualifications across the EU. It should enable the free movement of professionals such as doctors or architects within the EU. Similarly, the Commission introduced a new EU-wide digital procedure for the recognition of professional qualifications—the European Professional Card (EPC)—in January 2016. The procedure, currently available for general care nurses, physiotherapists, pharmacists, real estate agents and mountain guides, makes it easier for Europeans to work where their professional skills are needed. However, some regulated professions are excluded from these directives, for example lawyers, owing to consumer protection considerations. The EU has also introduced an improved notification procedure on specific reforms that member states need to implement for each profession. This provides transparency and pressure on governments to continue their reform processes.

Despite this progress, challenges remain. While the focus in the Services Package is mostly on entry barriers, the EU should caution against the possibility of member states substituting entry barriers with rules and regulations outside the scope of the proportionality test. These ‘hidden’ barriers, which affect operations of incumbent firms, can hinder long-term productivity even if entry barriers are lowered. Furthermore, some member states might not have the expertise, resources or governance structures to implement the necessary regulatory reforms. Evidence shows that countries with higher regulatory barriers in services, typically in Southern and Eastern Europe, are also the ones with the least effective governance structures to tackle services reforms (Van der Marel 2017).

## NATIONAL LEVEL: IMPLEMENTING THE SINGLE MARKET AND ADDRESSING ANALOG COMPLEMENTS NEEDED TO USE TRANSACTIONAL TECHNOLOGIES

### Implementing the single market

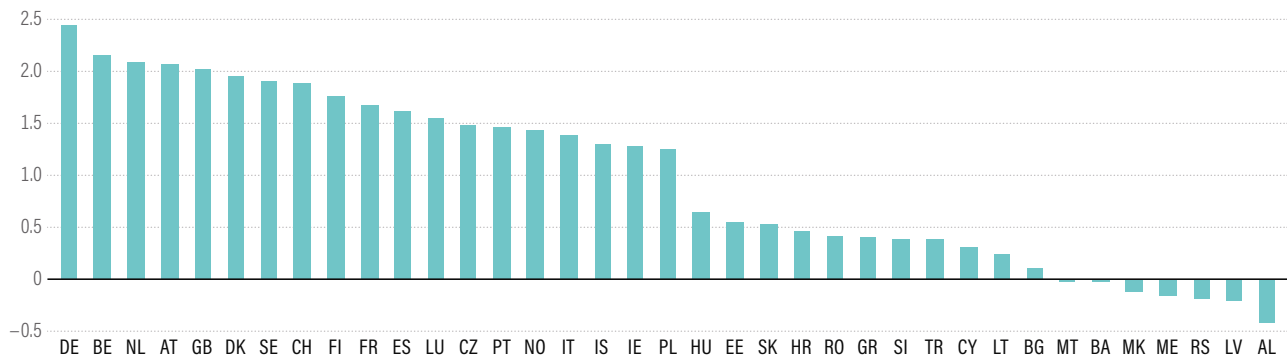
#### What is at stake?

The ability to trade within Europe is affected by regulatory differences at the national level. Firms across Europe experience unequal access to markets and customers not only because the integration of the DSM remains incomplete. Europe remains fragmented in various digital markets due, in part, to slow national legislative and regulatory processes, and also to conflicting interests between the supra-national and national governments, protectionism for incumbent digital players, and the low capacity of lagging governments to implement needed regulatory reforms. Product regulations and taxation can limit trade across borders in practice by raising the costs of compliance. Unevenness in the implementation of single market regulations can also raise uncertainty or costs for firms seeking to work across borders within the EU.

The performance of key national services sectors also hampers the digital economy to the extent that firms rely on these services for the successful execution of transactional technologies. Figure 6.1 illustrates the extent of variation in the efficiency of logistics services across Europe, underscoring why the use to many transactional technologies in practice is limited.

## FIGURE 6.1 Logistics Competence in Europe

Normalized LPI scores (global average=0; standard deviation=1)



Source: World Bank Logistics Performance Index, 2018

### What to do?

National governments need to do more to align their standards and regulations with those of their neighbors and fellow EU member states, if they want their firms and citizens to be able to take advantage of the greater choices and efficiency gains associated with the larger DSM.

Specifically, facilitating cross-border payments is critical for e-commerce and the exchange of any data or service across borders. Regulatory protection of national parcel delivery systems affects the availability and costs of cross-border delivery services, which constrain the ability of more vibrant e-commerce within Europe. The issue is not only about allowing for competition and integrated European services. It is also true that ‘last mile’ investments are needed at the subnational level for all jurisdictions to have the supporting infrastructure to use transactional technologies, including e-commerce.

## Going beyond ICT: ‘analog complements’ needed to use digital technologies

### What is at stake?

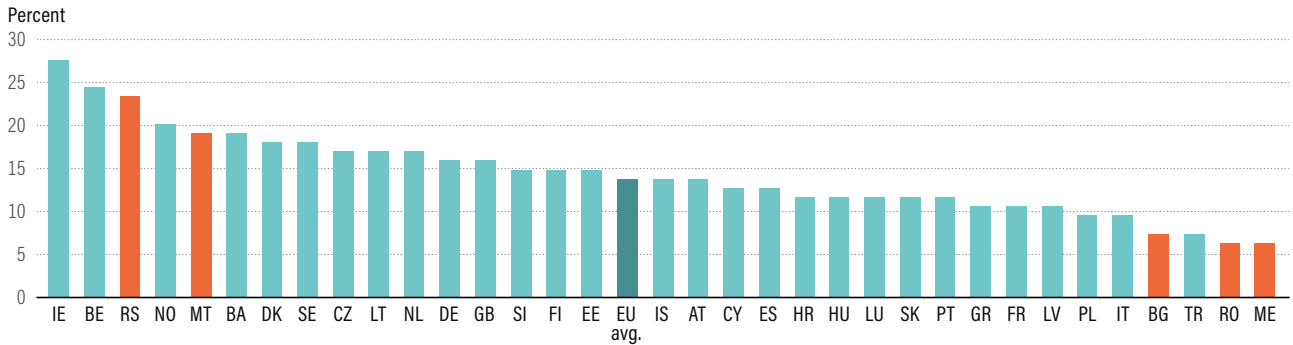
Work remains to be done to accomplish universal access to ICT, but this is not a sufficient issue on the agenda to support the use of digital technologies. Recall that Map 1.1 shows how access to ICT infrastructure and the use of the internet have expanded in recent years. While work is still being done to upgrade the speed of coverage in some areas, the other ‘analog complements’ are needed to ensure the uptake and use of digital technologies (World Bank 2016).

Even as the availability of ICT has become closer to universal, the uptake has been highly uneven. While there are broad north-south and east-west divides, there are some striking exceptions. It also underscores that the effectiveness of national efforts to support the agenda matter. EU membership is not sufficient; fewer than 10 percent of firms in Romania and Bulgaria meet even a minimum threshold of selling online and they are among the bottom five countries across Europe (along with Turkey, Montenegro and North Macedonia). On the other hand, the Western Balkan countries of Serbia and Bosnia and Herzegovina are among the top countries in the share of firms that use a B2B or B2C website or app to sell online in Europe (Figure 6.2).

That ICT infrastructure is necessary but not sufficient for a digital economy is widely recognized (World Bank 2019). Other dimensions that usually receive attention include supporting infrastructure (e.g., logistics, power) and skills. The ability to conduct financial digital transactions is also critical for transactional technologies.



**FIGURE 6.2** The share of enterprises that use a B2C website or app to sell online in Europe, 2018



Source: Eurostat and OECD

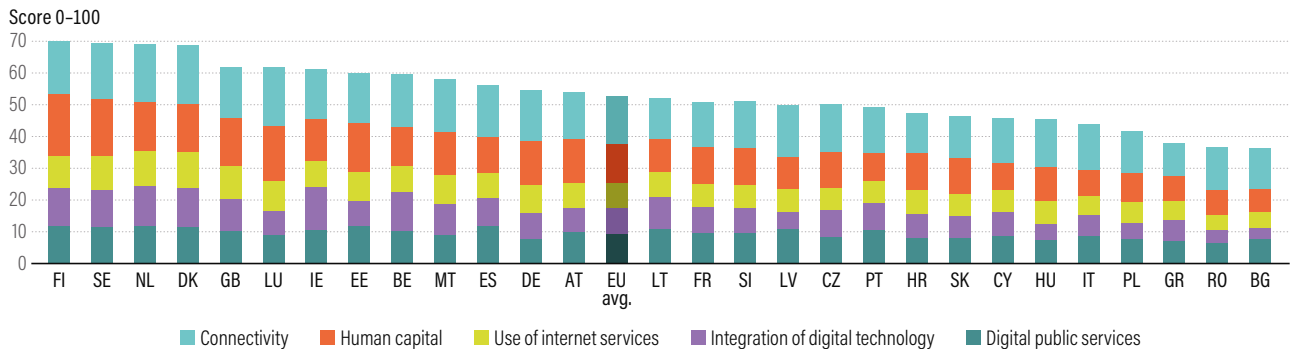
Note: The orange bars are countries in the Western Balkans.

But other dimensions also include the governance issues that affect the level of trust in using digital technologies, as well as tax issues on digital transactions (particularly when informal sector transactions are more common) (Szeles 2018; Andrews et al. 2018; Crespo et al. 2019). Pick and Nishida (2015) use a spatial framework to compare major world regions, finding innovation capacity, tertiary education, and judiciary independence to be important factors in explaining the spread of digital platforms worldwide, and in Europe in particular.

The Digital Economy and Society Index ranking includes ‘connectivity’ as one of its five pillars (Figure 6.3). It shows some of the varying gaps in connectivity across countries in Europe, but all the indicators of ‘readiness’ of European countries to develop and adopt data-driven technologies vary significantly, reinforcing the national dimension of the agenda too.

**FIGURE 6.3** Skills, internet use, and integration of technology differentiate EU member states

Digital Economy and Society Index ranking, 2019



Source: European Commission.

Attempts to develop country typologies arrive at similar groupings. Castelo-Branco, Cruz-Jesus, and Oliveira (2019) classify European countries into five categories of data-driven Industry 4.0 readiness, ranging from tech leaders such as Finland and the Netherlands, to tech laggards such as Bulgaria and Poland. The World Economic Forum’s *Readiness for the Future of Production Report* (2018) ranks 100 countries in terms of their preparedness to benefit from emerging technologies. ‘Leading’ European countries included the United Kingdom, the Netherlands and Germany, while Bosnia and Herzegovina, Bulgaria, Greece and Latvia are considered ‘nascent’ in their readiness for data-driven Industry 4.0. Similarly, the *DII 4.0 Global Industry 4.0 Readiness Report* (2016) ranked 120 countries using 23 measurements related to innovative capacity, demand factors, technological sophistication and others, finding that Western Europe and Scandinavia exhibit high levels of readiness, while Southern and Eastern Europe show medium to low levels of readiness.

Beyond the clear north-south polarization within Europe across digitalization indicators for the general population, Crespo et al. (2019) show that the geographic patterns of the uptake and use of digital technologies are more complex and imply nuanced policy recommendations. There are clear convergence trends across European regions and within countries for broadband access and indicators on the use of the internet. On the other hand, the scatterplots for e-commerce and e-government indicate that divergence dynamics have dominated over the past decade (Figures in Box 6.5).

**BOX 6.5** Modeling exercise underscores the importance of the ‘analog complements’ agenda in harnessing the benefits of digital technologies

Crespo et al. look at a range of variables that can help explain the patterns of convergence in broadband access and the use of the internet with the divergence in use of e-commerce and e-government. They then use trends in these variables to predict the extent of e-commerce

and the use of e-government across Europe by 2030. The results underscore the importance of addressing these ‘analog complements’ if countries, particularly in Southern and Southeast Europe, want to harness the gains of digital technologies.

**FIGURE B6.5.1** Convergence in European NUTS2 regions for broadband access and daily use of the internet, but divergence on e-government use and e-commerce use over the past decade



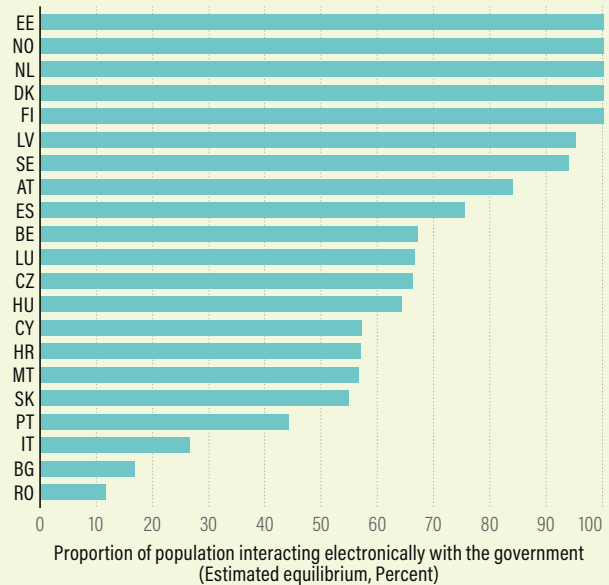
Source: Background paper by Crespo et al. (2019).  
 Note: NUTS = Nomenclature of Territorial Units for Statistics.

On the one hand, the e-government interactions do show within-country convergence to country-specific equilibria. The model estimating shows difference equilibria across countries, with 100 percent of the population predicted to use e-government in Estonia, Norway, the Netherlands, Denmark and Finland. However, for Italy the predicted equilibrium if trends continue is that just over one-quarter will reach it by 2030; and about 17 percent in Bulgaria and closer to 12 percent in Romania (Figure B6.5.2).

For e-commerce, the dynamics are slightly different. Surprisingly, access to broadband or income differences do not appear to be as robust a determinant of e-commerce adoption. Other institutional characteristics are likely to matter. Differences in tax regimes, the enforcement capabilities, regulations regarding consumer protection, and different restrictions to selling online, all varying at the national level, have been cited as important determinants of the digital divide (e.g., Gomez-Herrera et al. 2014; Coad and Duch-Brown 2017). Projecting forward to 2030, Crespo et al. (2019) projections result in club convergence for e-commerce. While Scandinavian economies, starting with relatively high values of the e-commerce variable, tend to converge toward a long-run equilibrium that corresponds to a high level of e-commerce use (at around 80 percent), the stable equilibrium projected for regions of many mostly Central European economies, such as France, Austria, Hungary, the Slovak Republic and the Czech Republic, tends to be closer to 60 percent (Crespo et al. 2019).

Source: Background paper by Crespo et al. (2019).

**FIGURE B6.5.2** Estimated steady state levels of e-government vary tremendously across countries, with convergence expected but very slowly in South and Southeast Europe



Source: Background paper by Crespo et al. (2019).

Among the key regulatory drivers are differences across countries in tax regimes, the enforcement capabilities, regulations regarding consumer protection, and different restrictions for selling online. If small businesses face greater tax burdens for income earned online, or if consumers are reluctant to have to pay sales tax for items bought online rather than through informal transactions in person, tax and governance issues can reduce the incentives to conduct online transactions. Consumer protections or restrictions of online transactions may be well intended, but in practice can make it difficult for smaller firms to comply, undermining the inclusive potential of these technologies.

### What to do?

Completing access to reliable and high-quality internet services and programs remains necessary, but much of the agenda lies in making more progress on the ‘analog complements’. This reinforces the point on implementing the DSM, as various regulatory issues still need to be updated to support digital technologies.

At the national level, policymakers need to look at how their choices are providing incentives—or disincentives—to the use of digital technologies. Lowering the administrative burden on firms, reducing restrictions on digital trade, enabling the reallocation of resources, including more flexible employment protection that can encourage gig work, updating insolvency regimes to encourage more risk taking, and strengthening skills and organizational capabilities, are all important elements. Clearly this is beyond a ‘digital agenda’; the key message is that indeed the agenda to support technology encompasses many traditional areas of the broader business enabling environment. Chapter 7 will pick up on the dimensions of the legal agenda, as well as the financial and skills agenda, while Chapter 8 will elaborate on more targeted support to technology creation and adoption.

# CONCLUSION

Strengthening the competitiveness of Europe's firms is central to its goals of raising incomes, building a global presence, and taking more of a leadership role in new technology. Addressing underlying issues that constrain the ability to develop digital markets is needed to achieve scale and the safeguarded free flow of data that is required for such markets to thrive. Policymakers need to do more to provide the enabling conditions to support the scaling-up of competitive transactional technology firms. Focusing on developing markets is both likely to lead to more opportunities that are inclusive across firms and locations, and they may also address some of the key constraints holding back more champion firms.

Beyond completing the regulatory framework of the DSM, there are a number of supporting measures that are needed to make the use of transactional technologies feasible and more attractive. While access to broadband has been a driving factor of the overall use of the internet, it has not been a robust determinant of the trends observed in the use of e-commerce and e-government. Policy steps aimed at bridging the digital divide in Europe need to go beyond enhancing convergence in access to infrastructure. Further homogenization of policies and institutional settings across countries are likely required for EU-level policy efforts toward a DSM to lead to an actual equalization of digital outcomes.

Much of the agenda discussed regarding scale and completing the DSM is relevant for informational technologies that require access to, and the potential movement of, large amounts of data. The next chapter discusses the regulatory agenda regarding data and the issues that new business models pose for competition authorities. These issues are of first-order importance for informational technologies, where data are a driving force of their value added. However, the regulation of data and data business models will matter for transactional technologies too. The relative priority between these policy agendas may differ by the type of technology, but there are areas of overlap such that taking these chapters together offers a more complete set of recommendations.

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# ANNEX 6

**TABLE A6.1** European Union's Instruments to Support Europe 4.0

	Euros 2014-20	Potential Resources 2021-27	Primary goals they contribute to		
			Competitiveness	Inclusion	Convergence
<b>Horizon 2020</b>					
<p><b>Horizon 2020:</b> Horizon 2020 is implemented via multi-annual work programs starting in 2014-15 and followed by others in 2016-17. The 2018-20 work program is the last work program for Horizon 2020. However, it is estimated that further work will be needed at a later stage to fill out the details for some of the priorities. Due to the way projects are categorized, funding for I4.0-related projects can be difficult to track and measure. Cifollilli and Muscio (2019) were able to identify 1,096 Horizon 2020-supported I4.0 projects with €2.6 billion in EU funding in the period 2014-17. During its final three years, Horizon 2020 is providing further investments of around €1,796 billion in the focus area of "Digitizing and transforming European industry and services". (Note: the total of estimated allocated budget will be allocated based on the components of the focus area. So, only a fraction of €1,796 billion can be attributed to convergence and integration.) Horizon Europe is meant to succeed the current Horizon 2020 program over the years 2021-2027.</p>	€77 billion	€94.1 billion	+	+	+
<p><b>InnovFin – EU Finance for Innovators:</b> InnovFin is a joint initiative launched by the EIB Group in cooperation with the European Commission under Horizon 2020. InnovFin aims to facilitate and accelerate access to finance for innovative businesses and other innovative entities in Europe. InnovFin financing tools cover a wide range of loans, guarantees and equity-type funding, which can be tailored to innovators' needs. Financing is either provided directly or via a financial intermediary, most usually a bank or a fund.</p>			+	+	
<p><b>The "Smart Anything Everywhere":</b> An initiative of the European Commission, under Horizon 2020, offers funding and support to SMEs to upgrade their products and services to the digital age. This is a key initiative of the Digital Innovation Initiative to help build the DIH network and boost innovation.</p>				+	+
<b>Investment Plan for Europe</b>					
<p><b>InvestEU Fund:</b> For the next long-term EU budget 2021-27, InvestEU will bring together the multitude of financial programs currently available and expand the successful model of the Investment Plan for Europe, the Juncker Plan. With EUInvest, the Commission will further boost job creation, investment and innovation. €2 billion allocated under the InvestEU Fund, in particular through its SME Window, will significantly contribute to the objectives of the Single Market Programme.</p>		€15.2 billion from EU budget, leveraging €650 billion in investments	+	+	
<p>With the <b>InvestEU advisory hub</b>, the Commission proposes to integrate 13 different advisory services currently available into a one-stop-shop for project development assistance. Its aim is to provide technical support and assistance to help with the preparation, development, structuring and implementation of projects, including capacity building.</p>			+	+	+
<p><b>European Fund for Strategic Investments (EFSI):</b> EFSI is part of the Investment Plan for Europe and implemented by the EIB Group, and helps to finance strategic investments in key areas such as research and innovation for SMEs. EFSI is a €26 billion guarantee from the EU budget, complemented by a €7.5 billion allocation of the EIB's own capital. The total amount of €33.5 billion aims to unlock additional investment of at least €500 billion by 2020.</p>	€26 billion from EU budget, leveraging €314 billion in investments		+		

	Euros 2014-20	Potential Resources 2021-27	Primary goals they contribute to		
			Competitiveness	Inclusion	Convergence
<b>European Structural and Investment Funds (ESIF) – 5 funds; ERDF, ESF (plus Cohesion Funds, and funds on rural and fisheries)</b>					
<b>European Structural and Investment Funds (ESIF):</b> ESIF is dedicating around billion to innovation in the period 2014-20, particularly through the European Regional Development Fund (ERDF), which aims to strengthen economic and social cohesion in the EU. About €12 billion is planned for investments in digitization under Thematic Objective 2 (Enhancing access to, and use and quality of, ICT).			+		+
			+		+
<b>European Regional Development Funds</b>					
<b>Smart Specialization Strategies (S3):</b> S3 is a tool to combine specialization and inter-regional cooperation to boost industrial competitiveness and innovation. More than 120 Smart Specialization Strategies have been developed across Europe, with more than €67 billion available to support these strategies, under the	€188 billion				
<b>European Regional Development Fund/ESIF</b> (2014-20 programming period), together with national and regional funding. All EU Member States with national-level S3 strategies (21 countries) include a focus on ICT and/or advanced manufacturing, and many of these strategies explicitly mention Industry 4.0. In the next generation of S3, to be implemented in the next programming period, support will most likely focus on intermediate and lagging regions, where specialization might be necessary due to the lack of capacity and resources, rather than leading regions where the prioritization process may be less applicable.	of which €67 billion				+
					+
<b>The European Social Fund (ESF)</b> is Europe's main instrument for supporting jobs and entrepreneurship, with financing of €10 billion a year and a priority to boost the adaptability of workers with new skills, and enterprises with new ways of working.	€120.4 billion	€101.2 billion (ESF+ combining with other youth and health initiatives)		+	
				+	
<b>Under Internal Market, Industry, Entrepreneurship and SMEs</b>					
<b>EU Programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises:</b> COSME aims to make it easier for SMEs to access finance and markets in the EU and beyond, and supports entrepreneurs by strengthening entrepreneurship education, mentoring, guidance and other support services. COSME also aims to improve business conditions in the EU by reducing administrative and regulatory burdens on SMEs. The program runs from 2014 to 2020 with a planned budget of €2.3 billion.	€2.3 billion			+	
				+	
<b>I4MS, ICT Innovation for Manufacturing SMEs:</b> I4MS is a European initiative supporting manufacturing SMEs and mid-caps in the widespread use of information and communication technologies (ICT) in their business operations. Under I4MS, SMEs can apply for technological and financial support to conduct small experiments, allowing them to test digital innovations in their business via open calls. The I4MS initiative is currently in its third phase, which started in September 2017, with a budget of €34 million.	Started with €34 million in 2017		+	+	
				+	
<b>Digital Single Market</b>					
<b>Digital Innovation Hubs (DIHs):</b> an initiative of the Digital Single market—is a pan-European network of one-stop shops where companies, especially SMEs, can get help to improve their business and production processes, and products and services by means of digital technology. The EU supports the collaboration of DIHs to create an EU-wide network, where companies can access competences and facilities not available in the DIH in their own region; for this, the European Commission launched the European catalogue of DIHs. This network will lead to knowledge transfer between regions, and will be the basis for economies of scale and investments in the hubs. For this, the Commission is investing €100 million per year from 2016 to 2020. More initiatives on DIHs will be supported from 2018 to 2020, with total investment of €300 million within the Horizon 2020 Programme.	€500 million (2016-2020)		+	+	+
				+	

	Euros 2014-20	Potential Resources 2021-27	Primary goals they contribute to			
			Competitiveness	Inclusion	Convergence	
<p><b>Connecting Europe Facility in Telecom:</b> The Telecom Facility is a key EU funding instrument to improve cross-border interaction between public administrations, businesses and citizens by creating digital service infrastructures and broadband networks. A €1.04 billion budget is earmarked for trans-European digital services for 2014-20. During this period, the Innovation and Networks Executive Agency (INEA) is responsible for the implementation of some €400 million of the CEF in Telecom budget in the form of grants. The WiFi4EU Initiative is a part of the CEF in Telecom work program, with €130 earmarked. The WiFi4EU initiative aims to provide free public Wi-Fi connectivity for citizens and visitor networks in 6,000 to 8,000 communities by 2020 across the EU and participating EEA countries (Norway and Iceland).</p>	€1.04 billion				+	+
<p><b>Connecting Europe Broadband Fund (CEBF):</b> CEBF was created to contribute to the achievement of the European Gigabit Society objectives. Investments will be made in underserved areas from the CEBF. EU member states and participating EEA countries (Norway and Iceland) are eligible for the funding. It aims to raise €500 million for broadband investment by 2020 and is expected to unlock total investments of €1.0 to €1.7 billion. The European Investment Bank, the European Commission, and National Promotional Banks from France (Caisse des Dépôts), Germany (KfW), and Italy (Cassa di Risparmio di Venezia) are among the CEBF's public investors.</p>	€500 billion				+	+
<p>The <b>Digital Europe Programme</b> is the EU's program to accelerate the recovery and drive the digital transformation of Europe. With a budget of €8.2 billion for 2021-27, it aims to build the strategic digital capacities of the EU and facilitate the wide deployment of digital technologies, to be used by Europe's citizens, businesses and public administrations. It will strengthen investments in supercomputing (€2.4 billion), artificial intelligence (€2.2 billion), cybersecurity (€1.8 billion), advanced digital skills (€600 million), and ensuring a wide use of digital capacity across the economy and society (€1.2 billion), including through Digital Innovation Hubs. Its goal is to improve Europe's competitiveness in the global digital economy and achieve technological sovereignty. Digital Europe will complement other EU programs, such as the proposed Horizon Europe program for research and innovation, as well as the Connecting Europe Facility for digital infrastructure.</p>	€8.2 billion		+	+	+	+
<p><b>European Data Strategy</b> <b>High Impact Project on European data spaces and federated cloud infrastructures:</b> The High Impact Project will fund infrastructures, data-sharing tools, architectures and governance mechanisms for thriving data-sharing and Artificial Intelligence ecosystems in the period 2021-27. This project will involve and benefit the European ecosystem of data-intensive companies, and will support European companies and the public sector in their digital transformation. The Member States and industry are expected to co-invest with the Commission in the project, which could arrive at a total funding in the order of €4-6 billion, of which the Commission could aim at financing €2 billion, drawing upon different spending programs.</p>	€4-6 billion		+		+	+



## CHAPTER 7

# INFORMATIONAL TECHNOLOGIES: SHAPING REGULATIONS FOR INNOVATION AND INCLUSION

Data are the lifeblood of the new economy. The free flow of data is a necessary pre-condition to the development of large data centers serving the continent and attracting data business to Europe. But, clearly, the rules for what types of data flow and for what purposes matter a great deal. On the one hand, the European Commission and European countries have been global leaders, pioneering the General Data Protection Regulation (GDPR) and using competition laws to address some of the new features of data firms. However, data and competition regulations still need to be updated to be fit for purpose in the digital age. These decisions will have significant impacts on the goals of competitiveness and inclusion.

The evidence from Chapter 4 highlights that the contributions of these technologies to Europe's triple objective have been shifting over time. Many of the earlier technologies have contributed to expanding opportunities for small and medium enterprises (SMEs), even as the impact on reducing the effects of geography have not been as strong. However, with big data becoming increasingly important, and the expanding use of artificial intelligence (AI) and machine learning (ML), the inclusion and convergence effects are weakening, while the gaps in uptake are widening. And whereas European firms were among the global leaders in creating earlier rounds of informational technologies, European start-ups are fewer than in other leading regions. Many European start-ups have even chosen to move to the United States to scale up. So, in addition to the rules around data and data business models, there is an agenda at the national and local levels in supporting digital start-ups, and in ensuring the availability of workers with higher digital skills to enable greater uptake of these newer informational technologies.

# INFORMATIONAL TECHNOLOGIES: SHAPING THE COMMERCIAL USE OF DATA FOR COMPETITIVENESS AND GREATER MARKET INCLUSION

Data-driven technologies present SMEs with both opportunities and threats. On one level, there is the question of how contestable new digital markets are. Are SMEs or new innovative firms able to compete? Given network effects and the benefits of having access to ever larger sets of data, big incumbents have clear advantages. The market power of the largest incumbent firms has become considerable, and companies such as Facebook, Amazon, and Google are receiving more scrutiny — and potentially face fines of billions of euros from the European Commission. The large market shares of these incumbents, combined with the characteristics of the markets in which they operate, especially in terms of network effects, can allow them to crowd out smaller firms and block the entry of new firms into the market. How well competition policy is made fit for purpose to tackle the new issues raised by the nature of new digital business models and the new types of market power they represent is critical in shaping how well entrants and SMEs can access new opportunities.

However, not only competition law impacts the contestability or inclusiveness of digital markets. Regulatory approaches to data policy also shape access to opportunities. This is true along three dimensions. First, if there are restrictions on sharing data, it is extremely hard for smaller firms and entrants to get the self-reinforcing network dynamics started. If SMEs and entrants cannot access data, it is hard for them to compete. However, second, the very security of some types of personal data can provide assurances on what companies (or governments) can do with data, in ways that are likely to gain traction with more consumers in the wake of data breaches and concerns about exclusion, discrimination and distorting information. Third, there are the costs associated with complying with the GDPR. Many of these are fixed costs, so they will be disproportionately higher for smaller firms. These costs can act as barriers to entry or limit firms' ability to take part in the data-driven economy in any significant way.

So, competition and data policies need to be looked at together in terms of the incentives they provide. Strong protections on personal data, combined with greater sharing of non-personal data and the more stringent review of how competition laws are applied to digital markets and business models, have the potential not only for more inclusive outcomes, but also to become a stronger source of comparative advantage for European firms internationally.

Faced with these realities, three key policy areas can better prepare Europe's smaller firms, and also help firms that are digitally lagging, to catch up and compete in the new digital age:

1. *Adapting competition policy for the digital age:* Given the features of digital business models, different criteria are needed to review how dominance in the market could be abused, while rules are also needed to ensure wider access to critical, non-personal data to support contestable markets — and innovation.
2. *Updating privacy laws to build trust that can be a source of comparative advantage, while also ensuring inclusion:* Rules on data privacy provide important protections, but in strengthening trust Europe's higher standards also have the potential to be a stronger source of comparative advantage internationally. At the same time, practical concerns addressing compliance costs, particularly for SMEs, need to be given attention.

3. *Strengthening the start-up ecosystem for new digital businesses to spur competitiveness and inclusion:* Moving from innovation to commercialization in informational technologies creates the need for new types of risk instruments. Updating the venture and growth capital systems would reinforce the potential for new firms to innovate and scale up in Europe. This should be coupled with more attention on digital skills, particularly as newer informational technologies require higher skills needs to be effectively deployed.

## EU LEVEL: ADDRESS TWO NEW CHALLENGES TO ACCESSING OPPORTUNITIES

Regulations affect the contestability of markets; they set the rules that determine just how open markets will be, and how easy it is for SMEs and new entrants to be able to access new opportunities. The network effects of platforms and the insights gained from harnessing large amounts of data are the source of efficiency gains and innovation. But these dynamics are precisely what raises new challenges to competition authorities, and to those safeguarding the value of consumer protections and data privacy within Europe.

Competition law seeks to protect against the abuse of a position of market dominance that comes with network effects and scale. It thus limits what incumbents can do to restrict entrants or SMEs from competing against them. But if data are increasingly the source of value in many digital businesses, restrictions on sharing data offer another way of restricting competition. Setting limits on what data can be collected and for what purposes can also stifle innovation. Europe's next steps will be critical in determining how well it balances size, innovation and contestability of markets for entrants and SMEs, i.e., how well its choice of rules balances the goals in its triple objective.

### Adapt competition policy for the data economy

#### What is at stake?

The data economy poses challenges for the enforcement of competition law and for preventing abuses of dominant market positions. This is increasingly being recognized. The World Bank Group's database of antitrust cases in the digital economy highlights Europe's global leadership, but also gives more granularity on the prevalence of different issues (Box 7.1).

#### **BOX 7.1** The MCP — World Bank Group Antitrust Database in the Digital Economy Framework provides global evidence on how countries are addressing new features that digital businesses raise in competition regulations

The World Bank Group is building a database and analysis of anti-trust cases from around the world. It provides evidence on where key issues are arising and how they are being dealt with. Europe clearly leads in the number of investigations it has opened regarding possible anti-competitive behavior in the digital economy — more than three times the share as North America. Transportation, commerce and software are the three most common, with ride-hailing services such as Uber attracting the most. Cases against Google in Europe, which have attracted significant attention and resulted in large fines, are in the fourth category of online search and advertising.

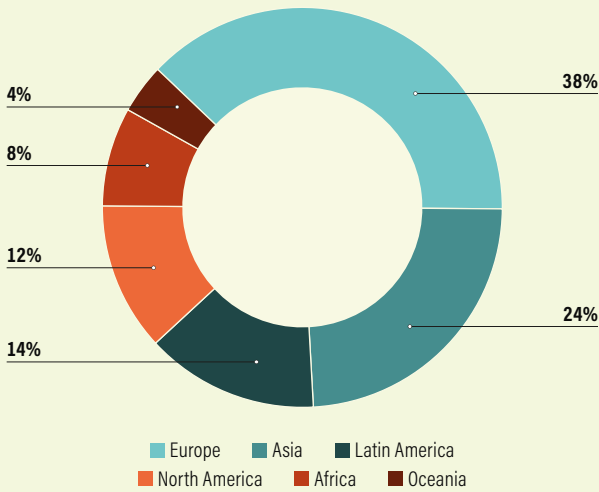
The analysis shows that the types of anti-competitive practices vary across sectors, driven by different business models and differences in the types of technologies that different sectors use. Whereas vertical restraints, such as self-preferencing, are more common in online retail, issues around collusion account for almost half of the transportation cases, while market dominance, such as tying and bundling, are more common in software and operating system disputes.

The analysis makes clear that the business model and underlying nature of the technology being used matter.

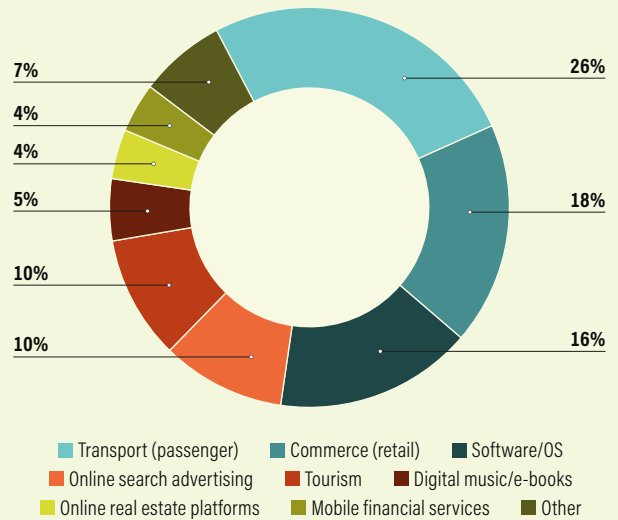


**FIGURE B7.1.1** Where are competition authorities investigating digital economy cases?

Europe leads among regions in launching investigations



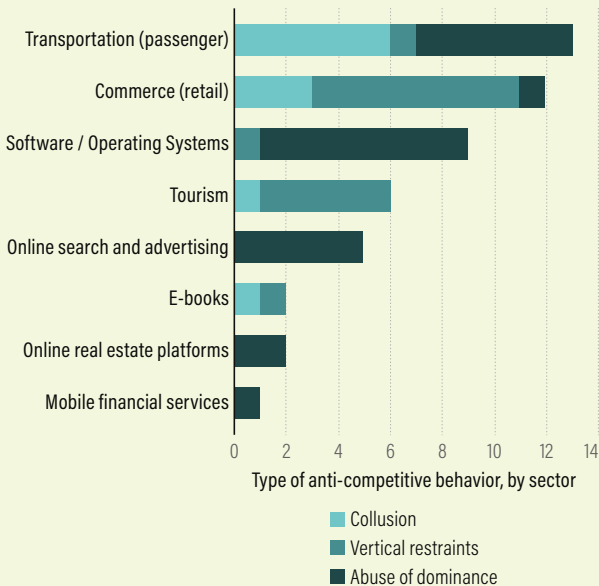
Three sectors account for 60 percent of cases



Source: MCP-World Bank Group Antitrust in the Digital Economy Dataset.

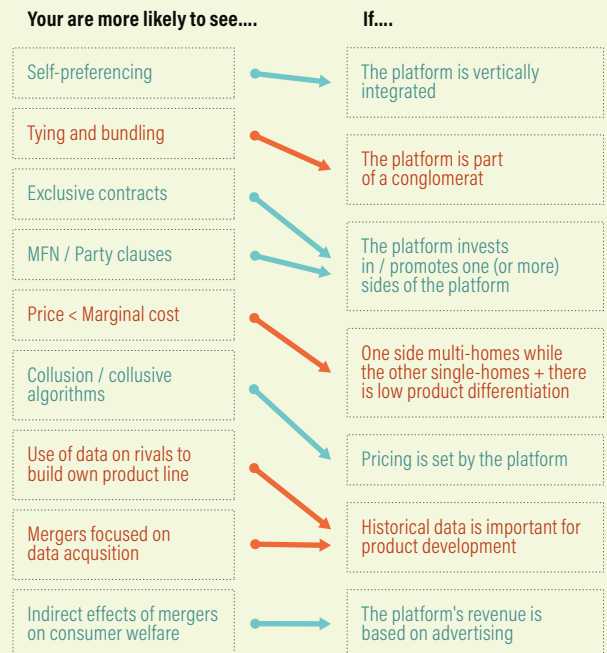
**FIGURE B7.1.2** Trends in the sectors and key types of anti-competitive behavior being investigated by competition authorities

Type of anticompetitive behavior, by sector



Source: Nyman, 2019; MCP-World Bank Group Digital Economy Framework

**FIGURE B7.1.3** The types of behaviors and effects depend on the business model



Source: Nyman, 2019; MCP-World Bank Group Digital Economy Framework.

Here, we focus on two aspects of how the data economy poses special challenges for competition authorities: (i) identifying what qualifies as anti-competitive conduct; and (ii) how to address the durable market power of digital incumbents.

## Identifying anti-competitive practices needs updating

There is a concern that the tools used to identify anti-competitive practices in traditional industries might not work well when applied to the data economy. Traditional potential triggers for competition oversight include the size and number of firms in a market and rising prices. However, in digital markets these do not necessarily signal anti-competitive behavior.

With network effects and multi-sided markets, size is potentially beneficial to both buyers and sellers that use the platform. As discussed in Chapter 6, scale is a critical feature of digital business models. Thus, the size or the number of firms alone cannot be sufficient in determining an abuse of market position. What matters are the rules and incentives that govern behavior on the platforms. Here, price is one potential dimension, but other requirements for participation likely matter more.

One challenge is that the prices for many digital services are low, if not free, especially in informational technologies. The hypothetical monopolist test, used by courts and competition agencies to define the relevant market and assess the firm's market power in that market, asks whether a hypothetical monopolist would be able to sustain a small, but significant, non-transitory increase in price. However, this test does not work when a firm does not charge for its product. More broadly, it is difficult to identify detrimental conduct of digital platforms when products and services are available for free, or for a very low prices for consumers (UNCTAD, 2019).

If the aim of a firm is to first gain market dominance, the trends in price might fail to identify behaviors that are detrimental to competition. It has been argued that Amazon achieved its market power in this way through its willingness to sustain huge losses for an extended period (Khan, 2017).<sup>1</sup> Over time, there is concern that platforms will indeed raise prices once there is no credible alternative. So, it is not that prices will contain no information, but the presence of many 'free' services means that prices alone will fail to flag potentially anti-competitive actions that would be of concern, and that it is important to keep looking at trends in prices over time.

Platforms can also extract costs not only through prices, but through other types of behavior, including restricting what users can do on other platforms (e.g., whether they can sell elsewhere, and whether they can sell at lower prices elsewhere). Operating systems can also tie or bundle software, preferencing their own products over those offered by competitors. Even if free, having to download an alternative service is a disadvantage over those that come built-in on a device. Some platforms can also 'strip' key features offered on competitors and build them into their own services.

Furthermore, the data economy presents new ways in which conduct that breaches competition law may be hard for consumers to detect. Digital incumbents may employ a practice known as self-preferencing—using data they have obtained from users to steer those users toward products that they offer in downstream markets and, through this, to undermine competitors in those markets. They also gain increasingly sophisticated knowledge of their users, enabling them to better target them with offerings—and potentially using this knowledge to target them by price.

## The durable market power of large incumbents means that markets will not auto-correct

In addition, the specific features of the data economy might render the market power of incumbent companies durable and difficult to challenge. That might decrease the market's ability to self-correct. It also raises the stakes in identifying the potential abuse of market power, as it can be very difficult in practice to undo its effects.

Information technology incumbents and transactional platforms are particularly durable in their market power. This is because key features of the data economy include low marginal costs, economies of scale, and powerful network effects, where the value of the platform or product for a consumer increase as other people use the same platform or product. This, in turn, amplifies the market power of large, established digital firms at the expense of smaller firms and new entrants to the data economy. Data markets are prone to "tipping", which refers to a situation in which one platform takes over the entire market (Furman et al., 2019). Once the market has tipped, it might be difficult for new entrants to challenge the incumbent's position. Even if new

entrants are able to develop a competitive product or service, because of the presence of network effects they might struggle to persuade a sufficient number of consumers to shift to the new product (Stiglitz, 2002).

However, the domination of the data economy by a few large incumbents to the exclusion of all others is not inevitable. Evidence from the European SMEs operating through digital platforms shows that platforms can be a window for the inclusion of smaller businesses and suppliers (De Marco et al., 2019). Chapter 4 of this report shows that platforms greatly facilitate the market entry of new firms. Nonetheless, if and when the abuse of market dominance by incumbents is not kept in check through the enforcement of competition policy law and other regulations, these same platforms can become tools for crowding out small and new businesses from the data economy.

The EU's data strategy recognizes the importance of supporting, and even requiring, the sharing of certain types of data, in order to make markets contestable, to encourage innovation and to ensure greater market inclusion. EU competition law provides the legal basis for forcing a firm to make certain data accessible that it has collected with other firms that need those data to compete in the market if specific conditions are met. The Court of Justice of the European Union (CJEU) has long recognized that, when specific circumstances are met,<sup>2</sup> a dominant firm's refusal to deal with a competitor can violate Article 102 of the Treaty on the Functioning of the European Union (TFEU), which prohibits a dominant firm from abusing its market position (Box 7.2). A refusal to grant access to data is no different.

### BOX 7.2 IMS Health's refusal to deal

The most relevant case for the discussion of a dominant firm's refusal to deal with a competitor in the data economy is perhaps the 2004 decision adopted in a case involving IMS Health, a company providing information concerning the sales of pharmaceutical products in Germany. IMS Health developed a "1860 brick structure" (protected by copyrights) that compiled information about the sales of pharmaceutical products. IMS Health's competitors sought to develop alternative structures containing the same information but were ultimately unsuccessful. When they sought to obtain a license to use the 1860 brick structure, IMS Health refused to grant such a license. The parties entered into a litigation and, when the case reached the CJEU, the court held that, in exceptional circumstances, a refusal to deal, such as a refusal to grant access to a brick structure, might violate EU competition law. The CJEU said that a dominant firm's refusal to deal is abusive if three conditions are met: (i) access to the firm's goods or service is indispensable to compete in the market, (ii) the refusal to deal would eliminate effective competition in the market, and (iii) there is no objective justification for such refusal. In addition, in cases involving a refusal to license an IPR, as it was the case in IMS Health, the CJEU has also required evidence that (iv) the refusal would prevent the emergence of a new product for which there is potential demand.

Source: Aridi and Petrovic, 2019; IMS Health v. NDC Health, 2004, ECLI:EU:C:2004:257.

## What to do?

To address these challenges, the European Commission and national competition authorities will need to revise the tools that they use to identify and address practices that are harmful for competition. We propose that the EU focus on key aspects of the data economy that can ensure a level playing field for its firms, including: (i) expanding access to data; (ii) preventing the anti-competitive use of data; (iii) shifting the burden of proof on whether a practice causes harm to competition; and (iv) pursuing a more balanced merger control.

### 1. Ensure access to those data that are necessary to compete in the market.

Data are the most precious resource in the new data economy, and access to data is critical for firms that develop and market informational, transactional, and even operational, technologies. Regulation (EU) 2018/1807 on the free flow of non-personal data, applicable as of May 28, 2019, is a positive step toward ensuring access to data, as it bans data localization requirements in EU member states unless justified on the grounds of public security. European Union competition law also provides the legal basis for forcing dominant companies to share data with rivals. However, determining whether it is desirable to compel a firm to share its collected data with competitors requires enforcers to balance between conflicting interests, including the interest of promoting competition and the interest of protecting incentives to innovate. If access to the data in question is essential to compete in a market, it could be argued that the policy that grants the widest access to data is the most desirable, because it will promote entry into the market and enhance competition. But developing a product or service that permits the collection of such data might require a large investment in R&D. The prospect of generating revenue from the collected data stimulates such investment in the first place but, knowing

that it will be forced to share its data with competitors, a firm might have no incentive to make these investments. Therefore, when granting access to data, it is necessary to balance between the need to ensure competition and the need to also preserve the incentives to innovate. Moreover, granting access to data might raise an additional concern when the data at issue are personal data. Privacy must be considered when determining whether it is not only desirable but also legal to force a company to share the collected data with a third party.

Past EU decisions make clear that, in some cases, a dominant firm's refusal to deal might constitute abusive behavior in violation of Article 102 TFEU. A dominant firm's refusal to grant access to data is not different (Case C-418/01, *IMS Health v. NDC Health*, 2004), where a refusal to grant access to data could be considered unlawful under EU competition law. In determining whether that is the case, the Commission's analysis will likely focus on establishing whether: (i) access to data is indispensable to compete in the market; (ii) the firm's refusal to deal with a competitor would eliminate effective competition in the market; and (iii) there is no objective justification for the firm's refusal to grant access to the collected data (Aridi and Petrovcic, 2019). When those requirements are met, a dominant firm's refusal to grant access to data will be considered abusive and the company might be compelled to provide such access. However, it is also important to recognize the limits of competition law. Article 102 TFEU only applies when a company holds a dominant market position and only if the three conditions discussed above are satisfied. If not, a refusal to grant access to data will not violate Article 102 TFEU. This is not to say there is a need to relax the existing doctrines to capture additional cases, but rather that a firm's refusal is unlikely to have detrimental effects on competition, and that it would be inappropriate to rely on competition law to compel a company to share the collected data with competitors. In other words, Article 102 TFEU does not create a general duty for dominant firms to grant access to data.

The new European Strategy for Data proposes several steps to ensure the availability of data. These include an enabling legislative framework for the governance of common European data spaces to facilitate cross-border data use, and to prioritize interoperability requirements and standards within and across sectors. The strategy

also proposes an 'Implementing act on high-value data sets'<sup>3</sup> to make more high-quality public sector data available for re-use, in particular in view of its potential for SMEs. The strategy also includes several potential legislative actions to address issues and provide incentives for horizontal data sharing across sectors. These legislative actions could focus on business-to-business data sharing, in particular addressing issues related to usage rights for non-personal co-generated data (such as IoT data in industrial settings), and address any existing hurdles hindering data sharing and clarify the rules for the responsible use of data (such as legal liability). In addition, actions should address the fostering of business-to-government data sharing for the public interest, and a re-evaluation of the IPR framework with a view to further enhancing data access and use.

Other laws governing data will also be relevant here. Although competition law might provide access to data in exceptional circumstances, it is not a tool that will provide systematic access to data to companies that need to compete in the market. Although competition law might force a dominant firm to grant access to its data in exceptional circumstances, this might not offer relief that is sufficiently timely (Box 7.3). To address the problem of timely intervention, the Commission should consider using remedies such as interim measures that provide more rapid relief in granting access to data (compared with preliminary injunctions).

### BOX 7.3 HiQ Labs Inc. vs. LinkedIn

The need to ensure timely access to data became evident in *HiQ Labs Inc. v. LinkedIn*, a dispute between a Microsoft-owned professional networking website, LinkedIn, and HiQ, a data analytics company that develops talent management algorithms, brought before the U.S. District Court in the Northern District of California. HiQ scrapes information that LinkedIn includes on public profiles and uses that information, in combination with its predictive algorithm, to offer business insights to its clients. HiQ's services permit clients, typically employers, to: (i) identify employees that are at the greatest risk of being recruited by other firms (information that, according to HiQ, permits the employer to offer incentives to retain valuable employees); and (ii) identify employees' skill gaps to then "offer internal training in those areas, promoting internal mobility and reducing the expense of external recruitment." HiQ has been scraping information from LinkedIn for several years but, in May 2017, LinkedIn sent HiQ a cease-and-desist letter, demanding that it stopped accessing and copying data from LinkedIn's server. HiQ filed a suit against LinkedIn asking, among other things, a court to issue a preliminary injunction forbidding LinkedIn from denying HiQ's access to data published on LinkedIn's website.

Both the district court and the U.S. Courts of Appeals for the Ninth Circuit sided with HiQ on the issue of the preliminary injunction. The Ninth Circuit found that there was a high risk that HiQ's business would not survive absent access to data posted on the LinkedIn

Interim measures (rarely used in the past decade) can be imposed on a dominant company to ensure timely access to data while investigations are ongoing. In markets where access to data is necessary for competition, the Commission may want to consider regulatory measures. As an example, the *Directive on Re-use of Public Sector Information and Regulation on Free Flow of Non-personal Data* aims at facilitating access to data by using tools other than competition law. Other examples include measures adopted to ensure data portability or tax incentives that could encourage firms to share their data with SMEs.

## 2. Prevent anticompetitive use of data.

The Commission and national competition authorities should scrutinize practices where firms use data in ways that are detrimental to competition, and ensure that companies do not use insights obtained from data analytics to harm competition. Such anti-competitive behavior can be especially harmful for transactional and informational technologies. In some cases, the anti-competitive use of data will fall within the existing theories of harm recognized in EU competition law. In other cases, the anti-competitive use of data may fall outside the theories of harm currently recognized under EU competition law, such as self-preferencing cases (see Box 7.4). In such cases, enforcers should not focus only on the short-term effects on price and output. Instead, they should focus on the longer-term effects that the challenged practice has on competition and innovation. Other cases include practices of dominant digital firms in a relevant market using insights obtained from data analytics to undercut rivals' prices within or in different markets. Existing legal doctrines provide the European Commission and national competition authorities with the legal basis for addressing cases in which companies use insights obtained from data analytics to then engage in price-related abuses.

website. The court acknowledged that granting access to data raised privacy concerns, but found that given that LinkedIn users chose to publicly share that data, privacy concern were not "significant enough to outweigh HiQ's interest in continuing its business." The Ninth Circuit also rejected LinkedIn's argument about "freeriding", reasoning that LinkedIn has "no protected property interest in the data contributed by its users, as the users retain ownership over their profiles." It also found that HiQ had raised serious questions of whether LinkedIn's actions to ban HiQ's bots were taken in furtherance of LinkedIn's own plans to introduce a competing professional data analytics tool. The Ninth Circuit consequently granted a preliminary injunction that ensured HiQ's access to data pending the decision on the merits.

Source: Aridi and Petrovcic, 2019.

### BOX 7.4 Apple vs. Clue and European Commission vs. Google

#### Apple vs. Clue

The case of Apple, which provides a platform (the App Store) on which third parties can offer mobile applications (apps) to iPhone users, provides an example of what critics claim is an anti-competitive practice in digital platforms. Apple provides its own apps to consumers and therefore competes with third parties that use Apple's platform. The concern is whether Apple uses the collected information to identify the most successful apps (or the most successful functionalities offered on those app) and then starts offering competing services. For example, in September 2019, Apple announced that plans to incorporate some of the core functionality of Clue, a menstrual health app, into its own Health app. Whereas Apple's Health app comes pre-installed in every iPhone and is free, Clue is free to download but monetizes its services by selling subscriptions and services to its users. One could foresee a situation in which Apple's decision to incorporate Clue's features, as well as the features of other health apps, could drive competing health apps out of the market.

Source: Aridi and Petrovcic, 2019.

#### European Commission vs. Google: the challenge of defining market power

To determine whether a company has significant market power, which is an essential requirement to show a violation of Article 102 TFEU or of section 2 of the Sherman Act, courts and enforcement agencies typically define the relevant anti-trust market and assess the firm's market power in that market. In defining the relevant market, they typically apply the hypothetical monopolist test (HMT) that asks whether a hypothetical monopolist would be able to sustain a small, but significant, non-transitory increase in price (SSNIP) for its products. The shortcoming of the HMT became evident in the 2018 Android decision, where the European Commission examined whether Google had a dominant position in the market where Android, its operating systems for smartphones, competed. Because Google does not charge smartphone manufacturers for a license to Android, the traditional HMT was of little help in identifying the substitutes to which consumers would switch in response to an SSNIP for Android.

## 3. Shift the burden of proof toward the digital incumbents.

The European Commission and national competition authorities should adopt a more interventionist approach when enforcing competition law in the data economy through shifting the burden of proof toward the incumbent on whether a practice causes harm to competition. The specific features of the data economy can render



the market power of digital incumbent companies entrenched and difficult to challenge. In other words, once a firm gains significant market power, the market might be unable to self-correct. This has important implications on the balance-of-error cost; a plaintiff carries the burden of proof to show that a firm's challenged behavior is unlawful, or for the dominant incumbent player to show that no harm is caused, or even that its behavior is favorable for consumers. For example, the Stigler Center Report suggests that anti-trust law should "recalibrate the balance it strikes between the risks of false positives and false negatives," because "[u]nderenforcement is likely to be costlier than previously thought because, among other things, market power of large technology platforms is more enduring."<sup>4</sup> The report suggests that courts should "impose less demanding proof requirements on antitrust plaintiffs." Similarly, the report Competition Policy for the Digital Era prepared for the European Commission in 2019 argues that "[t]he specific characteristics of many digital markets have arguably changed the balance of error cost and implementation costs."<sup>5</sup> It suggests that when markets are concentrated and barriers to enter the market are high, courts and enforcers "may want to err on the side of disallowing potentially anti-competitive conducts, and impose on the incumbent the burden of proof for showing the pro-competitiveness of its conduct." Therefore, courts and enforcement agencies should be less concerned about false positives when enforcing competition law in the data economy than they are in more traditional markets. EU enforcers already have been more assertive in enforcing competition law in cases involving technology companies compared with the United States. Nevertheless, this proposal could apply more specifically to mergers.

#### **4. Adapt the design of merger control to digital economy characteristics.**

Mergers can facilitate the acquisition or maintenance of market power in the data economy. One concern with mergers among firms that operate in the data economy is that a merger might escape the agency's scrutiny even if it poses a risk of substantially lessening competition. Parties are typically required to notify authorities of a planned merger only if the transaction meets a certain threshold, typically based on a firm's turnover. In the new data economy, which prioritizes growth over profit, the firms involved may not generate sufficient turnover to meet the threshold that would require merger notification. The Facebook-Instagram 2012 merger represents the most cited example of a transaction in which enforcement agencies failed to identify the acquisition as potentially anti-competitive. Some member states (Austria, Germany) have introduced alternative thresholds based on transaction value. Even when relevant authorities are notified, the analysis of a merger's potential effects might be challenging. Merger review requires enforcement agencies to estimate the counterfactual; that is, the market that would exist in the absence of the proposed merger—an assessment that might be particularly difficult in the data-driven economy, where markets evolve rapidly and in directions that are often difficult to foresee.

Another concern is that dominant players acquire innovative start-ups that could threaten their dominant position, possibly to incorporate its offerings into its own product lines—or to kill it. The striking decline in the number of new initial public offerings in recent years is attributed to the surge in acquisitions as the dominant exit strategy for many start-ups. While this may be advantageous for the founders of the start-up, consumers may well lose out if there are fewer alternatives and innovation that might upset the dominant position of incumbents is stifled.

The European Commission should reconsider the approach it adopts in defining the relevant market. The rapid expansion of some tech firms has been possible in part because of acquisitions that did not fall into the traditional categories of "horizontal" or "vertical" mergers, such as in Google's 2013 acquisition of Waze and Facebook's 2014 acquisition of WhatsApp. With a more flexible definition of the relevant market, enforcers could better estimate the potential effects of mergers on competition. The Commission's announcement in December 2019 that it will revise the Notice on the Market Definition appears to be a positive step in this direction. In addition, the analysis of the potential effects of the merger should not focus merely on prices, but should also consider other aspects of competition, such as innovation and quality. The European Commission has already recognized the importance that innovation has in its merger analysis in some of its past decisions (e.g., Case M.7932 Dow/DuPont).



It is also important that the European Commission and national agencies maintain a balanced approach in reviewing proposed digital mergers. A merger might have detrimental effects on competition, facilitate collusion among the remaining market players, and/or entrench an incumbent's market position and undermine the ability of other companies to enter in the market. However, mergers are also an important component of competitive markets. Synergies between two companies may permit them to offer better, more affordable, or more innovative products or services to consumers. This may be the case when an SME has a valuable business idea, but the incumbent possesses the financial resources and assets, as well as the necessary dataset, to bring the business project to fruition.

## Updating data privacy regulations for inclusive innovation

### What is at stake?

The European Union's groundbreaking GDPR makes great strides toward protecting individual privacy in the digital age. This not only protects how certain types of data may be used, but also by inspiring consumers' trust it could open new opportunities for business. Helping make the GDPR a source of comparative advantage for European firms would help in meeting the triple objective.

The regulation makes a distinction between personal and non-personal data (see Box 7.5). The discussion above regarding the wider sharing of data concerns non-personal data. The GDPR protects personal data. However, the distinction is becoming increasingly blurred. An increasing array of data will be identifiable to individuals. The use of personal devices, the growing presence of facial recognition cameras, and the spread of IoT sensors, not to mention self-driving cars, all have the ability to provide personal data, which can have enormous commercial value. Anonymized data and aggregated data would not fall under the GDPR, but otherwise, if there is personal data included, the regulations of the GDPR apply to the whole. As such, the nature of the regulations is important for understanding their economic impacts, and what they can mean for innovation, for contestability and for SMEs to be able to have sufficient access to data to be able to compete.

There are examples where protecting privacy has spurred innovation (see Box 7.6). And concerns about data privacy are growing, particularly as it becomes more apparent how data are being harvested and used where there are limited restrictions. There have long been concerns regarding state surveillance, but there is a growing awareness of how private firms can use data to exclude or price discriminate between customers, as well as to influence behavior and a larger set of preferences. What is at stake is not just consumption patterns or even voting, but larger effects on the allocation of credit,

### BOX 7.5 EU data regulations

**General Data Protection Regulation (GDPR).** The GDPR is a regulation in EU law on data protection and privacy for all individual citizens of the European Union. The GDPR aims primarily to give individuals control their personal data and to simplify the data protection regulatory environment. The GDPR directs businesses to put in place appropriate technical and organizational measures to protect individuals' data and to use the highest-possible privacy settings by default.

**Regulation on the free flow of non-personal data.** The regulation aims at removing obstacles to the free movement of non-personal data across EU member states and IT systems in Europe. It ensures the movement of non-personal data across borders, the availability of data for regulatory control, and easier switching of cloud service providers for professional users.

**EU Cybersecurity Act.** The Cybersecurity Act strengthens the EU Agency for Cybersecurity (ENISA) and establishes an EU-wide cybersecurity certification framework for digital products, services and processes. The certification framework will provide EU-wide certification schemes as a comprehensive set of rules, technical requirements, standards and procedures.

### BOX 7.6 Privacy protection can be a source of advantage

**Brighter AI Technologies** is a Berlin-based start-up established in 2017 to address anonymization needs using artificial intelligence. The solution it provides addresses privacy constraints set by the GDPR on the ways in which camera images can be processed. Traditional pixilation methods are usually not a preferred option, as they destroy many of the data essential for applications such as self-driving cars, retail analytics, and smart cities. Brighter AI offers AI-based anonymization that generates artificial faces based on an individual's attributes. This solution makes it possible to perform analyses such as demographic information, clothing style and line of vision without exposing the person's actual identity. It empowers companies to use publicly-recorded camera data for analytics and AI, while being compliant with the GDPR and other data privacy regulations worldwide. Brighter AI was named "Europe's Hottest Startup" by NVIDIA in 2018.

Source: Brighter AI, 2019; Lemonde, 2018.

housing, medical care, jobs, and the practice of political and religious freedom. As potential costs of not safeguarding data become clearer, demand for data protections and business models built on privacy-by-design may well rise significantly. European firms have an important head start (World Bank WDR on data, forthcoming).

However, this protection comes with costs, which can disproportionately impact SMEs. The GDPR can hurt SMEs in two ways. First, many of the costs of compliance are fixed, making them relatively higher for SMEs. Second, to the extent that the GDPR disincentivizes or prevents firms from sharing data, it reinforces the market position of firms that already have amassed significant data. Rather than pulling back on the level of protection, doing more to ensure data portability, interoperability and safeguarding the use of personal data is needed both to reduce costs and let more data flow freely — encouraging more inclusive opportunities — and to enable privacy itself to be a greater source of comparative advantage.

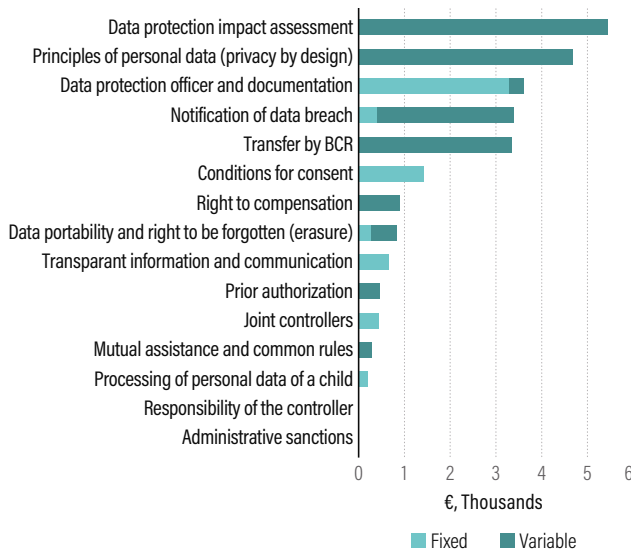
### Costs of compliance with the GDPR are more burdensome for SMEs

It is estimated that SMEs will face costs of between €3,000 and €7,200 for compliance with the GDPR, depending on the industry in question (Christensen et al., 2013). While some of the costs of compliance are variable, there are those that are fixed (Figure 7.1). Among the recent studies that seek to assess the economic costs of the GDPR, there is general agreement that SMEs will suffer most. Bigger firms have more resources and are thus more

capable of covering these fixed costs. In addition to harming the competitiveness of existing SMEs, compliance costs can also create barriers to entry, and therefore dampen the number of young firms developing and using digital technologies.

SMEs in certain industries are more likely to be impacted by the GDPR's costs than others. Articles 13 and 14 of the GDPR (the right of information and explanation for the data subject regarding the data processing) are particularly burdensome for cloud computing services providers, as they will bring operational difficulties in addition to increases in operational costs (Wallace and Castro, 2018; Chivot and Castro, 2019). Cloud computing providers are often unable to adhere to these articles during the phase of data collection (He et al., 2019). Stricter rules on handling and processing data are likely to inhibit the use of new AI technologies by raising the costs and limiting the scope of AI applications. In terms of costs, Article 22 states that humans need to review certain algorithmic decisions, which is likely to increase labor costs. Articles 13 to 15 give data subjects the right of information and explanation regarding data processing (including the right of access), which can also limit the use of some algorithmic decisions.

**FIGURE 7.1** Average expected direct costs impact, by type of article group



Source: Van der Marel, 2019.  
Note: BCR = Binding corporate rules.

However, GDPR compliance does take the size of firms into account in some instances. Certain rules and provisions, such as keeping records of processing activities or designating a Data Protection Office, do not apply to companies with fewer than 250 employees under most circumstances.

### Restricting the flow of data can be costly, especially for SMEs and entrants

The GDPR also contains a number of provisions that restrict the flow of personal data. To the extent that these provisions prevent or disincentivize the sharing of data between firms, they could further reinforce the market power of large firms that are already in possession of large amounts of data. Provisions that restrict data flows include the regulations around controller-to-controller or controller-to-processor data sharing, as well

as Chapter V, which impacts cross-border data flows across countries. These provisions increase the administrative burden of data-sharing agreements and, with violators liable for large fines (4 percent of turnover for infringements of the basic principles or data subjects' rights), may disincentivize and dampen data sharing among firms. Thus, to dispel the legal ambiguities that could discourage firms from sharing data, it might be beneficial to define specifically the cases where data sharing should be encouraged and even promoted. Compared with other agreements on data privacy flows, Europe's GDPR provides more protections and obligations; recognizing there may be other costs, the confidence in the protections it affords should be commensurate (see Box 7.7).

**BOX 7.7** The GDPR offers more protections and obligations than other privacy schemes (e.g., APEC's Cross-Border Privacy Rules system)

For non-European Union (EU) countries looking to introduce or update their approach to data privacy, the GDPR is often looked to as a model. However, it is not the only one. Comparing other models with the GDPR not only provides insights into the strengths of the GDPR framework, but also some of the challenges in getting more countries to adopt it. The Asia-Pacific Economic Cooperation's (APEC) Cross-Border Privacy Rules System (CBPR) is another model that many countries have adopted. It is a basic framework that provides for a type of "mutual recognition or acceptance" for APEC members that have signed up. Such a pragmatic approach is necessary to accommodate the vast difference in domestic laws among APEC members in order to reconcile the protection of personal data and international trade. It should be noted that APEC itself is a nonbinding organization unlike the EU; the rules do not have the same force of law as EU regulations do.

The CBPR was set up in 2011 and provides a minimum level of protection. Countries need to sign up to the CBPR, but also companies too; it is largely based on the Organisation for Economic Co-operation and Development's (OECD) framework of principles for data processing as provided in the 2013 OECD Guidelines. The CBPR is based on self-regulation, which implies that member states are not required to change their laws, but to voluntarily subscribe. As such, no modification of data privacy laws is needed.

The policies and practices must be assessed as compliant with the program requirements of the CBPR by a third-party agent, that is, the Accountability Agent chosen by the participating economy (which should represent an independent APEC CBPR system recognized public or private sector entity). The policies and practices should also be enforceable by law. To date, the members are the United States (2012), Mexico (2013), Japan (2014), Canada (2015), and the Republic of Korea (2017), as well as Australia, Singapore and Taiwan, China (2018).

*Source:* Van der Mare, 2019.

Unlike the GDPR, the rules and provisions apply to data controllers, not to data processors. In the CBPR there is no storage limitation, which in the GDPR is otherwise set in Article 89. The data breach notification for the data controller is only encouraged in the CBPR and is not mandatory as in the GDPR. In addition, the rules that consider the handling of special personal information is stricter in the GDPR, as well as the automating processing and decision making (including profiling). Also, there are hefty fines for noncompliance in the GDPR, which are absent in the CBPR.

To date, there is no study that empirically or theoretically assesses the economic cost and/or benefits of CBPR membership. However, industry representatives such as the Information Technology and Innovation Foundation (Cory, 2019) have stated that the data privacy scheme is an attractive one as the system focuses on core principles and accountability, while recognizing the diversity of the member states' regulatory frameworks. However, it should be noted that the level of protection is lower, which makes compliance easier — but which may not then provide the same degree of trust by consumers and citizens.

Given that the GDPR requirements must be met by foreign companies doing business in Europe, its standards are being met by a much larger share of firms. It is also true that countries outside Europe, when looking at developing their own data privacy laws, have an incentive to be compliant with the GDPR to facilitate the ability of their own firms to do business in Europe and not have multiple standards to meet. Given the costs of compliance, this will need to be weighed for a large number of smaller firms that likely will never trade with Europe. Exceptions for certain provisions can be made for smaller firms, but this can also introduce some distortions for firms to stay below that threshold.

The practical challenges of combining the GDPR and a strategy of sharing non-personal data are apparent. Europe's public sector has a great deal of data that, in theory, could be shared, expanding opportunities across the spectrum of firms. However, this is not happening all that widely in practice, as protocols to ensure proper collection, storage and use of data can be challenging in practice. One extreme example is in health care. The collection of comprehensive electronic health records collected through national health systems offers incredible potential to harness big data analytics to make breakthroughs in smart health services. However, this is still largely stymied, as solutions on data privacy have not been agreed upon, or are not met (Fraunhofer background paper, see Box 7.8). If appropriate protocols can be made on how to access and use sensitive data for human-centric purposes, many more people would likely be willing to share more data. Making progress on providing the needed safeguards that still allow for the sharing and use of data is critical.

### BOX 7.8 The GDPR and innovation: Realizing the benefits of secured data sharing

For a stronger single market, Europe needs to move forward on safeguarding free flows of data. Building on the framework of the GDPR, Europe is in a good position to enable more data sharing with trust, which entails progress on portability, interoperability, and safe sharing of public and private data that can spur more innovation — and more inclusive economic opportunities.

Artificial intelligence is seen as a key dimension for innovation within the digital economy, particularly as cloud computing's power grows and sensors make more data available. The potential is particularly high in bringing together data from different sources, or in repurposing data to provide new insights in new applications. But this is where the GDPR's restrictions need some updating, to provide the desired privacy, while also encouraging innovation that could provide important new services and sources of efficiency gains.

Demonstrating that sharing data can still protect important dimensions of privacy while enabling innovation and improving services will be important in having this approach become a larger source of comparative advantage. Technology may offer some solutions, as through blockchain, but regulatory approaches and demonstrated enforcement will matter too.

This would allow Europe to capitalize on the data that it does have that are currently under-utilized. This agenda is of first order importance

*Source: Fraunhofer background paper.*

for informational and transactional technologies. While industrial technologies are currently largely unaffected, as most do not (yet) use personal data, personalized 3D printing and self-driving cars will make this agenda more widely relevant soon enough.

Recent news also shows that more steps are needed to ensure that privacy interests really are protected. The Financial Times' November 13, 2019, exposé on the 100 top health-related websites and the extent to which cookies and trackers were used before consent was given, and the extent to which data were sold to third partners, including outside the EU and, in some cases, with identifiable information, including internet protocol addresses, has raised alarm bells. While outside the EU, the news that Google has a partnership with Ascension — a non-profit health-care provider with more than 150 hospitals in 20 states in the United States — has raised concerns among patients, whose permission was never sought and who were never consulted over the terms of what the access to data were, or what the liability protections might be if data protections were breached.

So, work remains to be done, not only in ensuring trust and that the GDPR is in fact implemented, but also overcoming the practical challenges of respecting the GDPR, while at the same time enabling innovation, productivity gains and new services to emerge that can build on the confidence of data sharing with trust.

Responses to COVID-19 have also brought home some of the trade-offs associated with approaches to data privacy (Box 7.9). The implications are of first order importance for health outcomes, but also have implications for competitiveness — which approach is endorsed by political systems and the market, and also in contributing to reducing the number of cases, and the need for lockdowns or reduced face-to-face activities.

### BOX 7.9 Europe's efforts to develop and disseminate privacy-friendly COVID-19 tracing apps: a tale of two approaches

Data-driven technologies have been widely used globally for monitoring and tracking the spread of the COVID-19 pandemic. In Europe, home of the GDPR, the outbreak is forcing a debate on the trade-off between privacy and public health. Unlike more invasive surveillance technology used to track infections in other parts of the world with lower privacy standards, the European approach adheres to embedding safeguards to encrypting data and anonymizing personal information. For example, public health officials are promoting apps that can analyze Bluetooth signals between mobile phones to detect users who are close enough to infect each other. The data are temporarily stored on the phones; if users later test positive for the virus, the app alerts anyone who has been around them in preceding days so they can isolate themselves. This, along with other measures, is intended to help health authorities better contain the spread of the coronavirus, while allowing countries to resume some of their public life. One such effort is by the Pan-European Privacy-Preserving Proximity Tracing (PEPP-PT), a group of about 130 European researchers, activists and technologists, which released a code for an app that adheres to the three principles: interoperable (pan-European), GDPR compliant (privacy-preserving), and proximity

tracing. However, the use of these tracing apps that are powered by people's health data gives rise to privacy concerns that may prohibit widespread adaptation — key to the success of such apps.

European governments have been debating approaches to Bluetooth-based COVID-19 tracing apps, some arguably taking stricter measures to protect individuals' privacy than others. Countries including Austria, Germany, Switzerland and Estonia have heeded the guidance of European privacy experts on the importance of applying the principle of "data minimization" — collect only what you need — when developing such apps. These countries have opted for a decentralized approach where data are processed on the individual's phone rather than in a centralized government server. These apps use an interface (API) developed by Apple and Google, which has built-in privacy protection that prevents governments from collecting more information than they need. This approach does not collect location data and encrypts the user's identity.

However, other countries such as France and the United Kingdom decided to develop their own interface, which allows a wider range of personal data to be collected, and then stored and processed in a

centralized server. While this approach may allow governments to conduct more granular analysis on the spread of the coronavirus, it does raise concerns about the risk of surveillance and hacking.

Both approaches follow the EU's privacy legislation and, with the lack of a binding pan-European approach to such tracing apps, it has been

*Source: authors.*

Apple and Google's clout that has started to influence governments toward decentralization. A great challenge that remains, however, is how to convince people to download the app and use it. Early results of these tracking efforts will be closely monitored to gauge the effectiveness and popularity of these approaches, and their fit for Europe.

## What to do?

The GDPR may impose costs that disproportionately impact the competitiveness of SMEs and new firms. However, some would argue that the economic costs by no means outweigh the privacy benefits provided by the new regulation. Minimum wages, environmental rules, and health and safety standards all impose constraints on a company's ability to compete, but few would argue that those regulations are undesirable or should be removed. Instead, regulations should be tailored in a way to minimize the detrimental effect on competition. Indeed, the GDPR itself sought to minimize the effects of existing heterogeneity in privacy regulations by harmonizing the regulatory frameworks in EU member states. European firms now have one overarching legal framework governing data privacy to which they must adhere. It is important to further monitor the impacts of the GDPR and introduce necessary adjustments to minimize any undesired consequences in the ability of companies to develop and leverage AI and other advanced data analytics methods (without infringing individuals' privacy).

The European Commission might consider four proposed revisions to the existing data privacy regulatory framework:

### 1. Do more to encourage and enable data sharing by rightful data owners

Data portability and interoperability standards are key to helping reduce the costs of compliance, as well as addressing concerns that SMEs have adequate access to data to be able to compete. Nevertheless, the specifics and granularity of this standardization that enables data sharing are still to be defined. In this context, there have been European efforts to define the principles for shifting the focus from organization to human-centric approaches<sup>6</sup> with the goal of establishing an ethical data economy (see Box 7.10). Sharing of data is one key principle of this approach. According to these principles, the production, collection, and processing of data should be interoperable and harmonized in a structural format to enable the automated flow of data. The details of this harmonization are still undefined, but Europe is well positioned to define and propagate these standards.

#### BOX 7.10 Human-centric approach for the data economy

The human-centric approach advocates transforming the focus from organization-centric and technology-centric to human-centric. The goal of this approach is data use that builds on the rights of individuals through the application of six guiding principles:

**Access:** Access by default. Access to data according to various access rights (e.g., business-to-business, business-to-government) should be facilitated by technical or legal solutions and support.

**Share:** Reusable by default. Datasets need to be interoperable and harmonized in a structured format to enable the flow of data in automated processes.

**Act:** Human-centric by default. Individuals are guaranteed access to their personal data and the means to manage the reuse of their data without lock-ins or impediments that inhibit access or portability (e.g., timeliness).

*Source: EU2019, FI, 2019.*

**Trust:** Ethically sustainable by default. Building trust in data use and data-driven technologies requires strong respect for human rights, and transparency, reliability and the inclusion of all stakeholders. Data security and privacy by design should be integral parts of business and service development practices.

**Innovation:** Level-playing field by default. Data market access should be open to all on a fair and nondiscriminatory basis for the benefit of everyone. Undistorted competition in data markets should be guaranteed.

**Learn:** Renewal by default. A thriving data economy requires societal change, and constant reevaluation and up-scaling of people's skills and organizational capabilities.



## **2. Reduce legal ambiguities to facilitate firms' compliance with the GDPR**

Companies should not be reluctant to develop new products or services because of a concern that they will fail to comply with a regulation that they are unable to understand. The European Commission might therefore consider adopting measures that clarify existing legal provisions, in particular the conditions in which the sharing of data is permitted or even encouraged.

## **3. Consider sector-specific privacy regulations**

Data do not have equal relevance in all industries. For example, concerns that the GDPR could hamper a company's ability to rely on AI might have less weight in manufacturing and automation processes, where a large part of the collected data is nonpersonal, than in other applications, where access to personal information plays a more fundamental role in the company's business (such as in informational and transactional technologies). Hence, focusing on revising the legal framework for industries in which the GDPR might have more relevant consequences should be a priority for the European Commission.

## **4. Focus on ways that data should not be used**

The GDPR tries to limit what data are collected. However, experience shows that individuals are willing to share their data quite widely. Asking for consent has its limits in terms of providing much protection to users; there is often no alternative if wanting to use the service and the details are too overwhelming for many to read. And new data technologies, including the IoT and the expanding use of facial recognition software, are likely to increase the amount of personal data that are available exponentially—and not necessarily collected with consent. However, if much personal data are shared, many still have strong assumptions that there are still protections on how these data can be used. Two areas of particular concern regard health data and financial data. Particularly in financial data, there is an explosion of using 'alternative data' to predict credit-worthiness, and thus who is targeted for marketing and on what terms. However, concerns about bias in the algorithms and the use of protected information provide legitimate grounds for policy.

## **5. Algorithms and not just data need to be subject to review to adequately protect privacy and the legitimate use of data**

Algorithms can be complex and they can use a lot of data to function. But they can be subject to unintended sources of bias, particularly of marginal groups. This can be due to shortcomings in the data used to train ML algorithms, for example, the overwhelming use of white men's health data as the 'normal' benchmark, and the underrepresentation of different racial and ethnic groups used to train facial recognition algorithms, etc. It may well take sophisticated use of AI itself to test other uses of AI; the skill set of regulators in this field is rising.

## **6. Ensure that fines are proportional, particularly in cases of SMEs,**

to address concerns that the GDPR could discourage practices that are beneficial for consumers. For example, the European Commission might consider the option of imposing a fine only on repeated infringers and show lenience toward unintended violations.



# NATIONAL LEVEL: SUPPORTING START-UP ECOSYSTEMS FOR DIGITAL FIRMS

More can be done to provide the enabling environment that would allow firms to become global leaders. Chapter 6 already discussed the importance of achieving scale and that the continued fragmentation across markets with-in Europe acts as a barrier. In completing the digital single market it is also relevant for information technologies to have the incentive and ability to achieve scale. Second, more so than transactional technologies, informational technologies, particularly ones developing AI or ML applications, do rely on more research. While Europe does support R&D, as discussed in Chapter 8, much of it is in operational technologies rather than in this space. This is in contrast with China, the Republic of Korea and the United States, which are more actively supporting R&D in AI (see Box 7.11). A third dimension is moving from the initial innovation to its commercialization, of going from the idea to scaling up in practice. Tellingly, some digital start-ups may choose not to incorporate and scale in Europe—a trend observed in the past 10 years. Examples include: LogMeIn, a Hungarian SaaS and cloud-based services company that moved to Boston and listed on NASDAQ in 2009; AVG, a Czech-Dutch antivirus company

## BOX 7.11 Comparing governments' approaches to supporting innovation in artificial intelligence

Among digital technologies, artificial intelligence (AI) is singled out as an increasingly important general purpose technology that can be used across multiple sectors and applications: the European Union has initiated efforts to become a leader in AI-based technologies. However, the World Intellectual Property Organization's 2019 report on AI finds that the United States, China and Japan have become the dominant players.

Unlike other technology areas, firms, not universities, dominate AI patenting activity. Of the top 30 AI patent applicants 26 are firms. Many of these companies are in Japan, but the American companies IBM and Microsoft are big players: IBM has the largest portfolio of AI patent applications with 8,290 inventions, followed by Microsoft with 5,930. Universities dominate AI research in some fields, with Chinese universities dominating others. Chinese organizations make up 17 of the top 20 academic players in AI patenting. There are 167 universities and public research organizations ranked among the top 500 patent applicants; 110 are Chinese, 20 from the United States and 19 from the Republic of Korea. Only four European public research organizations feature in the top 500 list and the highest-placed European institution, Germany's Fraunhofer Institute, comes in 159th. The quality of the patents and not just the quantity matters, but these numbers reinforce the level of ambition to excel in this area.

Being able to set global standards for AI is a top strategic goal for China. While the AI Government Readiness Index (2019) ranks China fifth in Asia-Pacific and 20th globally, China is expected to quickly rise in rankings. Central government funding and an abundance of data give China a big advantage in AI. It is not just that China's population is the largest in the world, it is that a far higher share of transactions are conducted digitally—from social media to purchases. Without the same restrictions on data sharing, particularly with the government, there are large centralized efforts to harness these data.

In the Rep. of Korea, the surge in R&D is extremely focused, largely conducted by Samsung and in the areas of AI and software, with some additional investments in ICT hardware. A smaller economy, the focus is on the Rep. of Korea's existing champion and its ability to stay on the frontier of a growing industry. The stakes are high, so the government is concerned that if standards or breakthroughs occur for which Samsung is not prepared to engage quickly (if it is not the leader itself), it risks seeing significant slowdown in its growth.

The United States is ranked fourth in the world for government AI readiness and has been slower in developing a national AI strategy. The recently launched Artificial Intelligence Research and Development Strategic Plan emphasizes high-impact research, such as AI safety, and a common environment and resources for AI development. The federal government has made a US\$2 billion investment in the Defense Advanced Projects Research Agency's AI Next campaign. But this initiative is less comprehensive than the AI strategies of other leading nations, and lacks new funding and clear policy objectives. In addition, the United States lags others in terms of data availability that is an important resource for Industry 4.0.

Currently, the U.S. Government is not funding AI projects in the same way as China, but there are discussions among policy makers, given that scale matters so much in AI, as to whether this is an example where concerted public funding would be the most effective approach. Currently, Alphabet, the parent company of Google, Facebook and Amazon are all pouring considerable funding into AI—for its commercial value, not necessarily for strategic gains in national security. However, it could be the case that, where the introduction is first made commercially and then specialized for national security applications, so some other technological breakthroughs could have also occurred.

The EU is increasing its annual investments in AI under Horizon 2020 to connect AI centers across Europe and support the development of AI

applications. The AI policy also considers the societal impacts of AI and addresses issues such as brain drain, retraining, and modernizing the education and training systems. It addresses the need for formulating an ethical and legal framework for AI building on the trust generated by the GDPR. Data are an important resource for AI companies, but it raises privacy and intellectual property dilemmas. The GDPR addresses the right to privacy, the issues of transparency and control of personal information by citizens, and explicit consent.

*Source: Bal and Gill, 2019; Hallward-Driemeier and Nayyar, 2018.*

In 2018, the EU and the member states published a coordinated action plan to promote the development of AI in Europe. The Coordinated Plan on the Development and Use of Artificial Intelligence Made in Europe states an ambition “for Europe to become the world-leading region for developing and deploying cutting-edge, ethical and secure AI, promoting a human-centric approach in the global context.” Similar coordination efforts are being undertaken in robotics.

### **BOX 7.12** LogMeIn’s journey from Hungary to the United States

Originally named 3am Labs, Inc., LogMeIn was founded in Budapest, Hungary, in 2003 as a provider of cloud-based communication and collaboration tools. After an initial period of growth in which it raised US\$30 million in venture funding, primarily from US-based VC firms, the company moved its headquarters to Woburn, Massachusetts, and went public on NASDAQ in 2009. Today, 750 of its nearly 3,000 employees are located in its new headquarters in Boston, and it has offices in seven other countries around the world, including Hungary.

that listed on NASDAQ in 2012; and Spotify, a Swedish music streaming service that debuted on the NYSE in 2018 shortly before moving to New York City (see Box 7.12).

There could be a number of reasons for start-ups to relocate to the United States, from traditional issues on regulatory standards, taxation and access, to skills. The primary focus here is on venture capital (VC) markets, particularly given the larger role of intangible capital in technology start-ups that raises new challenges for which the system in Europe is still not well suited. The changing skills agenda was the subject of a recent World Bank report (World Bank, 2018), but high-level messages are highlighted here.

## Deepening venture capital and growth capital in Europe

### What is at stake?

Venture and growth capital are an essential financing sources for start-ups—young and innovative companies with high growth potential. These financing forms, notably provided in the form of external equity, are not to be seen as a substitute for traditional, mainly bank-centered, SME financing instruments. Rather, they serve a specific and restricted group of SMEs and mid-caps (including start-ups) which, nevertheless, significantly contribute to the innovativeness, productivity and development of the overall economy.

Two features of technology start-ups can exacerbate the challenges of attracting investors. First, unlike traditional start-ups with physical assets, digital business models have more intangible assets. There is thus limited collateral to use for securing financing. Without physical assets, debt financing is harder to qualify for, but intangible capital is also riskier for investors and the information asymmetries can be greater.

Second, with network effects, capital may need to be patient longer than for traditional start-ups as it takes time to reach critical scale (Box 7.13). Furthermore, many venture investors lack the expertise needed to assess and evaluate advanced informational technologies, so AI and other deep-tech-based start-ups often need to seek out VC or private equity (PE) firms that specialize in such technologies, which limits their pool of potential investors. The state of venture and growth capital in Europe in this sector is often cited as a significant impediment to commercializing R&D.

### **BOX 7.13** Scale-up challenges faced by digital technology start-ups: beyond financing

In a case study of digital start-ups in the Czech Republic, Aridi and Querejazu (2019) found that digital technology start-ups face a range of challenges above and beyond those faced by “traditional” start-ups. These challenges included getting access to the necessary data needed to develop their products and services, to prototyping and demonstration sites, and gaining customers. Getting early customers often requires a plant manager or executive willing to “take a chance” on a new company and product where others will not. These first customers provide critical access to data needed to develop the start-up’s digital solutions, train algorithms, model systems, and calibrate equipment. They also provide testbeds and demonstration sites for the start-ups to pilot and validate their technologies in real-world environments. Other challenges are related to technology integration, and interoperability and long procurement timelines.

Even after start-ups have validated their products with one or more early adopters, additional customers often feel pilots are necessary to demonstrate the solution’s benefits, and, more critically, ensure that the solution will not disrupt important company processes and operations.

*Source: Aridi and Querejazu, 2019.*

Pilots include an assessment period, after which the adopting company may spend some time deliberating whether to adopt at a wider scale. This pilot-assessment-deliberation process can extend procurement timelines by years and severely restrict the cash flow. One way around this pilot process is to partner with incumbent solutions providers, which can provide start-ups with access to a broad customer network under a trusted brand name. For example, Sewio, a Brno-based start-up that offers a real-time indoor location tracking system that helps its clients track objects in locations where GPS does not work, partnered with Cisco and PwC, which were both looking for new products to expand their IoT capabilities. Such partnerships often lead to acquisitions of start-ups by the established providers. In fact, there have been two such acquisitions in the Czech Republic in the past two years: Cleerio, which develops mapping and asset management tools, was acquired by BioNexus in 2017, and Stories, developer of a business intelligence AI assistant, was acquired by Workday in 2018. These acquisitions seem to be the feasible route for scaling up such data-driven start-ups.

## **Maturing of the European risk capital markets**

The justification for public support in the area of SME financing in general, and external equity financing in particular, is rooted in the presence of information asymmetries in the relationship between financier and recipient, the presence of fixed costs of investment, and the existence of positive externalities originating from SMEs’ innovation activities. In the private equity/venture capital (PE/VC) markets, the long investment cycles can also deter private investors, especially in early-stage financing, while public agents can be considered as more “patient” investors (Kraemer-Eis et al., 2019). Questions about the exit strategy will also weigh on investors’ interest to participate.

This year’s State of European Tech report boasts that “European tech companies are performing at a level exceeding the expectations of all but the most optimistic” (State of European Tech, 2019 report). The report documents the unprecedented performance of European tech companies and their investors. Compared with 2015, when European tech start-ups received US\$10 billion in investments and still suffered from a late-stage funding gap, 2019 saw a record US\$35 billion capital invested, with 40 European tech companies each able to raise more than US\$100 million. In 2018, European VC funds raised more than US\$13 billion after years of steadily increasing fundraising success. Around US\$50 billion was raised in cumulative VC funds between 2015 and 2019, compared with just US\$20 billion between 2010 and 2014. The report claims that there are currently at least 174 European tech companies that have scaled to a valuation of over US\$1 billion, 99 of which are venture-backed companies (United Kingdom, Germany, and France were home to most of these firms). The report focuses on how VC financing is expanding at impressive rates within Europe. But the larger context is that the extensive gap between Europe and the United States remains. For Europe to remain competitive and enable its start-ups to scale in Europe rather than establish themselves in the United States continued significant improvements are needed.

Even though risk capital investment is growing rapidly in Europe, investment activity is still much lower than in the United States. There was €20.1 billion invested in venture capital and growth stage deals into over 6,500 companies in Europe in 2018 (up from €13.6 billion in 2014), compared with about €120 billion invested in VC and growth-stage deals in the United States in 2018 (Table 7.1).

**TABLE 7.1** European risk capital market, 2018

	Amount (€, billion)	No. of companies
Seed Stage	0.7	1,350
Startup Stage	4.9	2,475
Later-Stage	2.6	758
Growth Stage	11.9	2,106
Total	20.1	6,689

Source: Invest Europe.

The European Business Angels Network (EBAN) also tracked €745 million in European angel investments in 2018. Angel activity is notoriously difficult to track, as many independent investors are not part of formal networks and do not report their investments. EBAN estimates that the total size of 2018 European angel investments could be as high as €7.45 billion. For comparison, a 2017 report estimating the size of US angel activity found US angel investments could be as high as US\$24 billion per year.

**The European and US VC markets differ in several important ways**

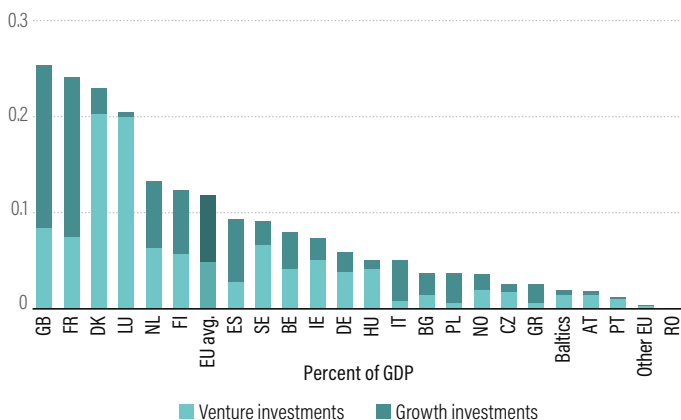
Modern private equity was popularized in the United States, particularly around the San Francisco Bay area, which gave

the United States a head-start in venture investing that it has never surrendered. The United States is the most attractive VC market in the world due to its large, integrated market, and the extreme agglomerations of start-ups, highly skilled talent, research infrastructure, and networks found in hubs such as San Francisco and Boston.

There are impediments to the development of a vibrant venture and growth capital market in Europe as a whole, where the presence and accessibility of alternative funding avenues is underdeveloped for SMEs, for the following reasons:

- *Venture activity is highly concentrated within Europe but new hubs are emerging.* As shown in Figure 7.2, the United Kingdom and France lead in VC activity as a percentage of GDP, reflecting the importance of the London and Paris metro areas as the preeminent VC hubs in Europe. Outside of London and Paris, there are smaller hubs, such as in Berlin, Dublin and Amsterdam, and large regions with little or no VC activity. The recent EIF report “The VC Factor” claims that the six largest European hubs receive one-third of all investment activity. However, new emerging hubs are changing the status quo. Interestingly, 40 percent of the financed start-ups are located in cities with more than one million inhabitants while, at the other extreme, 25 percent operate in smaller cities, with a population of less than 100,000. In many areas in Europe, start-up firms rely instead on investments from friends and family or on bank finance, which is traditionally less structured to support innovation financing. But it is noteworthy too that successful start-ups are emerging across Europe, including in the CESEE region (see Box 7.14).

**FIGURE 7.2** Venture and growth investments as a percent of GDP by country, 2018



Source: Invest Europe.

Note: EU = European Union; GDP = gross domestic product.

**BOX 7.14** The rise of the Central, Eastern and Southeastern Europe (CESEE) region start-ups

Despite the shortcomings in the enabling factors for innovation, the CESEE region has a promising and relatively vibrant start-up market. There are currently about 9,000 start-ups in the CESEE region. Some of the most prominent unicorns that originated from the region, primarily in the ICT sector, include: Avast and AVG (founded in the Czech Republic), UiPath (Romania), Teleric (Bulgaria), Allegro and CD Projekt Red (Poland), TransferWise and Skype (Estonia), and LogMeIn (Hungary). Visible success stories, particularly in the ICT sector, are possible due to a high quality of talent pool in technical fields, as well as the presence of multinationals. The presence of global support players further enhances the creation of success stories, such as Startberry, Campus Warsaw, and Hub Raum.

Source: Innovation Finance in the CESEE Region, 2020; Vienna Initiative working group on Innovation Finance (WB, EIB, EBRD).

- *European funds rely heavily on government sources* — particularly the European Investment Fund — in their fundraising, with government sources accounting for 18 percent of all funds raised in Europe in 2018, while almost no US funds rely on government sources for fundraising (Invest Europe). But it should be noted that beyond the financial resources themselves, there is an important signaling effect. EIF’s due diligence process and active monitoring ensures high governance standards and results in a recognized validation effect of supported proposals. This signaling effect effectively helps to crowd in additional investments. In regions with comparatively less developed markets, the EIF’s presence is even more relevant.
- *European funds are heavily focused on seed- and start-up-stage funding*, with relatively fewer deals and investments in later-stage VC funding, as can be seen in Table 7.1. This is because there is substantial public support available for investments in pre-seed, seed- and start-up-stage companies, but not for later stage VC and growth stage financing, while European institutional investors such as pension funds have focused their investments in buyout funds. This lack of later-stage funding used to constrain the growth prospects of start-ups looking to scale up, forcing them to look to other markets for investments. This funding gap has been addressed recently with more European tech firms being able to raise US\$100 million.

## What to do?

### Addressing regulatory barriers that hinder more vibrant VC markets

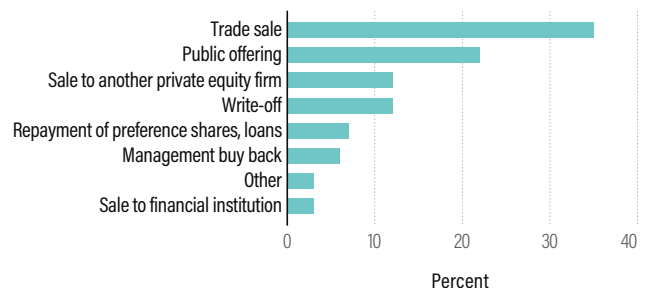
Three priority areas for reform that could strengthen the development of VC markets in Europe are to:

*Address restrictions on share ownership.* Complicated European finance laws hinder the ability of European start-ups to distribute company shares to employees. Currently, laws governing stock options are determined at the country level, rather than at the EU level, meaning that as a company expands beyond its national market into EU markets it must navigate a complex set of financial regulations. Because of this, the average European late-stage start-up will have only distributed about 10 percent of its shares to employees, compared with 20 percent for US companies.

*Where they are still high, lower costs, and the time of proceedings and the uncertainty associated with resolving bankruptcy to avoid discouraging investment up front.* Resolving insolvency can also be challenging in Europe. The ability to resolve insolvency through bankruptcy is an important feature of healthy entrepreneurial ecosystems, as bankruptcy allows for and encourages ‘second chances’ among entrepreneurs. The EU in general ranks highly in the Doing Business Resolving Insolvency indicator (measuring the time, cost and outcome of insolvency proceedings, including bankruptcy), with seven European countries ranking among the top ten global performers; however, Croatia, Hungary and Greece all rank below 60 in terms of resolving insolvency.

*Address regulations that discourage initial public offerings (IPOs).* Weak exit conditions can discourage more private investment. Europe has relatively fewer IPOs and more M&As (Figure 7.3). There are regulatory challenges related to conducting IPOs in Europe, particularly for smaller and mid-cap companies. These challenges include “one-size-fits-all” regulation governing IPOs for companies of any size, high administrative costs for companies looking to go public, and restrictions on investors’ ability to access IPO markets. These barriers to IPOs will also decrease the incentives of early stage investors to invest, as IPOs are one of the key mechanisms for successful exit from their investments.

**FIGURE 7.3** Venture capital exit routes in Europe, 2018



Source: Invest Europe.

The VC system is not the only relevant part of the start-up ecosystem. In deciding whether to scale up in Europe or move to the United States, other factors will weigh too. Regulatory standards in many sectors are higher in Europe, from environmental standards, food safety standards, labor standards, etc. These reflect European values, and consumers have demonstrated a willingness to pay for them. Taxes too, both corporate and personal, are higher in Europe, as the World Bank's Golden Growth report demonstrates, reflecting more generous social safety nets and public investments, and higher quality-of-life decisions in work-life balance (Gill and Raiser, 2012). Some entrepreneurs would prefer to make a different trade-off, locating in a jurisdiction that poses lower regulatory standards and lower taxes. There are important values at stake here. The values and standards that European firms meet earn a certain reputation for quality that has a competitive dimension to it. It raises the bar on what firms have to do to succeed; some will take that challenge on, but not all.

## Skills to use data-intensive technologies effectively

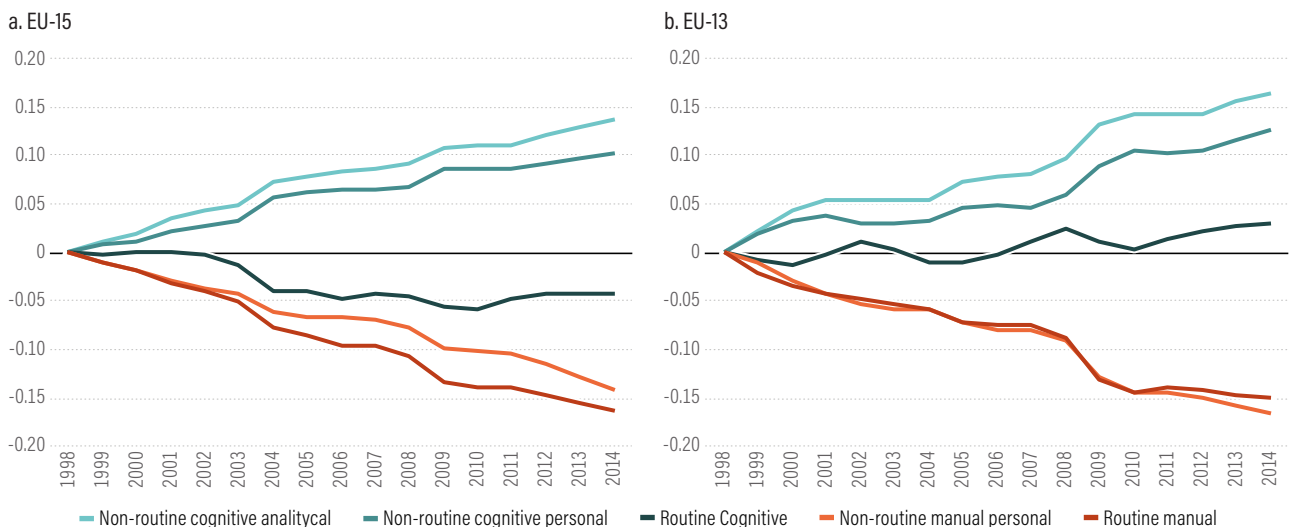
### What is at stake?

A final dimension is skills. Whereas the need for digital skills is not that demanding for users of transactional technologies or earlier informational technologies, the need for more sophisticated digital skills to use some of the newer informational technologies is rising. And the skills needed to be creators of new digital platforms are also much higher.

The World Bank (2017 and 2018) discusses the skills agenda in light of new technologies, highlighting the different gaps across countries and regions within Europe. It also documents how the demand for skills is changing, particularly the rise of cognitive and non-repetitive skills over manual and repetitive skills (Figure 7.4). The pace of change is also accelerating, raising some uncertainty over the types of skills that will be in demand in the future. Lagging regions face an even greater challenge because this uncertainty on how the demand for skills is changing is coupled with gaps in even basic digital skills and literacy — over 30 percent of the populations of Greece, Croatia, Romania, and Bulgaria have no digital skills (European Commission, 2019).

**FIGURE 7.4** Jobs and the demand for skills are becoming more intensive in non-routine cognitive tasks and less intensive in manual tasks

Occupation-specific task intensities, aggregated for each country and standardized over time, regional averages, 1998–2014



Source: World Bank 2017, Growing United.

Note: Malta, Cyprus, and Luxemburg excluded because samples are too small.



In international comparison, China stands out in its efforts to invest in science, technology, engineering and mathematics (STEM) skills, including digital skills. The number of university degrees in science and engineering rose from half a million in 2000 in the top six European countries (France, Germany, Italy, Poland, Spain and the United Kingdom), comparable to the United States, to about three-quarters of a million by 2016, whereas China's grew from just under 400,000 to 1,700,000. European countries do graduate a higher proportion of PhDs in STEM, but China is again closing the gap (Zwetslootz, 2020).

## What to do?

Developing an Industry 4.0-ready workforce starts with digital literacy and skill development in primary and secondary education. Students should be exposed to basic coding and other digital skills as early as primary school. While basic skills are the bare minimum, this will not be enough to equip lagging regions to develop and adopt Industry 4.0 or advanced digital technologies. That will require advanced digital skills, such as data analytics, data management, networking and programming, for both new workforce entrants and for the existing workforce. Tertiary education curricula should be updated to meet changing skills requirements. Universities can ensure that their curricula remain relevant with guidance from industry advisory boards to weigh in on current and future skills needs (see World Bank, 2017, and Valeria et al., 2018, for more detailed analysis and recommendations).

Another lesson is that Europeans need to become lifelong learners. Lifelong learning is becoming ever more important as the pace of technological change accelerates. To do so, it is not all about technical skills. Adaptability requires a strong foundation of cognitive and socio-emotional skills. So, while teaching technical skills receives much attention, these should not come at the expense of building foundational skills in school. Second, a model of precision training can be effective at targeting specific skills to specific workers. It is demand driven, with training often supplied in the workplace by employers. Third, stronger industry-school/university partnerships should be strengthened to ensure that the technical skills that students learn are not already out of date when they graduate. Governments should be encouraged to give the private sector and enterprises a greater role in driving content and delivery in vocational training, higher education and adult learning (Valeria et al., 2018).

What is also striking is that Europe appears to be doing relatively little to try to attract skills from outside Europe to come to Europe. The United States has an excess of H1 visa applications. China is offering big incentives to have expat Chinese return to China (Zwetslootz, 2020). There is mobility within Europe, but little effort to bring in much external top talent. It is appropriate that many countries in Europe are strengthening the education systems in light of shifting demands for skills from firms. However, to have globally cutting-edge firms, aiming higher to train and attract world-class talent will need greater prioritization.

## CONCLUSION

New informational technologies represent both a great opportunity and a threat to Europe's inclusion objective. While these technologies can help small firms to close existing productivity gaps with their larger competitors, they can only do so if these smaller firms can compete on a level playing field and if they have the internal capabilities needed to adopt these technologies. Without these enabling conditions, many European SMEs risk falling further and further behind.

The recommendations in this chapter—doing even more to adapt EU competition policy for the data economy, updating data privacy regulations to safeguard inclusive access to data, and building a more flexible and supportive ecosystem for start-ups—can help support both competitiveness and inclusion, helping to address what could otherwise be sources of growing tension across Europe's triple objective and helping Europe realize its potential in the new economy.

The big question for Europe is whether the rules around data themselves will become a source of comparative advantage. Demand from a wider set of consumers globally could well grow. How well the standards and practices for ensuring data portability, interoperability and the sharing of data develop in practice will be critical in the coming months and years. As trade and investment partners already have to apply with European regulations to do business there, European values are already having an influence beyond the region. Reinforcing this, if Europe can build more and larger firms that comply with the various ‘privacy by design’ features, there is an opportunity for European values to have a wider influence in setting global standards.

## Notes

1. The same is true for some transactional technologies that also rely on scale, e.g. Uber and Lyft ride-sharing services.
2. Those exceptional circumstances arise when (1) access to the firm’s good or service is indispensable to compete in the market, (2) the firm’s refusal to deal with a competitor would eliminate effective competition in the market, and (3) there is no objective justification for the firm’s refusal.
3. Slotted for Q1 2021 under the Open Data Directive.
4. Stigler Committee on Digital Platforms, Final Report 16 17, 2019.
5. EU Report on The Competition Policy for the Digital Era.
6. The Finish EU presidency in 2019 has been centered around defining the general principles for guiding the European data economy toward a human-centered, successful, balanced directions. See more here: <https://www.lvm.fi/-/common-rules-will-strengthen-the-development-of-data-economy-1023147>

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## CHAPTER 8

# OPERATIONAL TECHNOLOGIES: SMOOTHING THE DIFFUSION OF TECHNOLOGY FOR GREATER INCLUSION AND CONVERGENCE

## INTRODUCTION

Accelerating the diffusion of operational technologies is necessary for their productivity benefits to be shared more widely. Given Europe's competitiveness in operational technologies, policy makers should continue building on this source of strength while working to counter the concentrating effects of these technologies among larger firms and existing production hubs. However, more can be done at the EU level, and the national and local levels, both to deepen R&D efforts, and to enable additional firms and locations to support the use of operational technologies.

European firms are strong in creating operational technologies. Operational technologies represent the bulk of R&D efforts in Europe, and a significantly larger share than in the United States or Asia. This underscores why many of Europe's global technology leaders are in operational technologies. However, Europe's levels of R&D remain below those of comparators in North America and Asia, and funding is tilted more toward the public sector.

There is scope to improve the contributions to inclusion, although there are some natural limitations on this potential. Scale has always mattered in these technologies that tend to be quite capital intensive, requiring larger upfront investments. As such, larger firms are more likely to make the investments in researching and developing these technologies, and in using them in production. However, some breakthroughs, for example, 3D printing, in

principle could help reverse the emphasis on scale. More can also be done to help some smaller firms enter into more specialized activities and become linked into larger value chains. Building firms' capabilities to upgrade can also expand the set of firms that can use these technologies effectively.

The bigger scope for policy is affecting the contributions that operational technologies can make to geographic convergence. This is both through the allocation of investment funds to support applied R&D, in improving the business environment in ways to support the ability to use these technologies, and through efforts to build firms' capabilities that are usually delivered via local programs, so there is a geographic dimension here too. However, two caveats need to be kept in mind. First, some concentration is to be expected given agglomeration economies. However, these leading locations are not set in stone. Investment can help create new centers of excellence over time.

The second caveat, however, is that whereas operational technologies in manufacturing served as an important engine of convergence for Eastern Europe in the 1990s and 2000s, this pattern has been stalling in recent years. Operational technologies may not have the same converging role going forward if existing factories are upgraded to be 'smart factories', rather than pushing for new factories to be built in new locations. Efforts to upgrade business environments and firms' capabilities are all the more important.

A two-part strategy is needed to address the contribution of operational technology to the digital dilemma. On the one hand, more can be done to strengthen R&D efforts and to close the gaps with the goals that countries have set for themselves. But investments in innovation need to be balanced with a focus on diffusion to expand the use of the technology. This chapter examines EU-level programs, such as European structural and regional funds that aim to address upgrading and regional convergence. It is complemented by the need to raise capacity building for national- and regional-level policies and institutions on how these programs are implemented. As with the other chapters, it is not that this agenda applies only to operational technologies, but from the perspective of operational technologies these are the policies of first order importance to address its contribution to the digital dilemma.

## EU LEVEL: BALANCE FUNDS FOR RESEARCH WITH FUNDS FOR TECHNOLOGY DIFFUSION

### Europe's performance in R&D: Four key gaps

#### What is at stake?

Doing more innovation matters; whether it is the next big (giant) thing or an incremental change, innovation is a key driver of productivity growth. However, it is not the case that all firms can or should be trying to push out the frontier. Nor should the aim be to distribute resources and efforts equally across locations

#### BOX 8.1 Policy debate: Is leapfrogging possible?

In seeking to expand market inclusion and geographic convergence, a key question is whether it is possible to leapfrog technologies. In regions that have only limited exposure and use of data-driven technologies, the question is whether they can jump to the more sophisticated ones. Being able to leapfrog, taking advantage of new technologies or operating on the frontier, without having to do all the work and investment of incrementally reaching that level, is attractive. The desirability is clear. The question is how feasible it is. This chapter looks at the question at both ends of the performance spectrum, in terms of R&D, and whether resources should be spent to bring the regional best up to the frontier, as well as toward the lower end of the distribution where more support to adoption could raise productivity. The recent divergence in rates of adoption of smart automation, as well as of higher skilled informational technologies, would indicate that convergence will not happen on its own.

The question of leapfrogging is not unique to operational technologies. But as these technologies are more R&D intensive and the large majority of publicly supported R&D funds are allocated to operational technologies, approaches to both frontier research and support for technology adoption are discussed in this chapter.

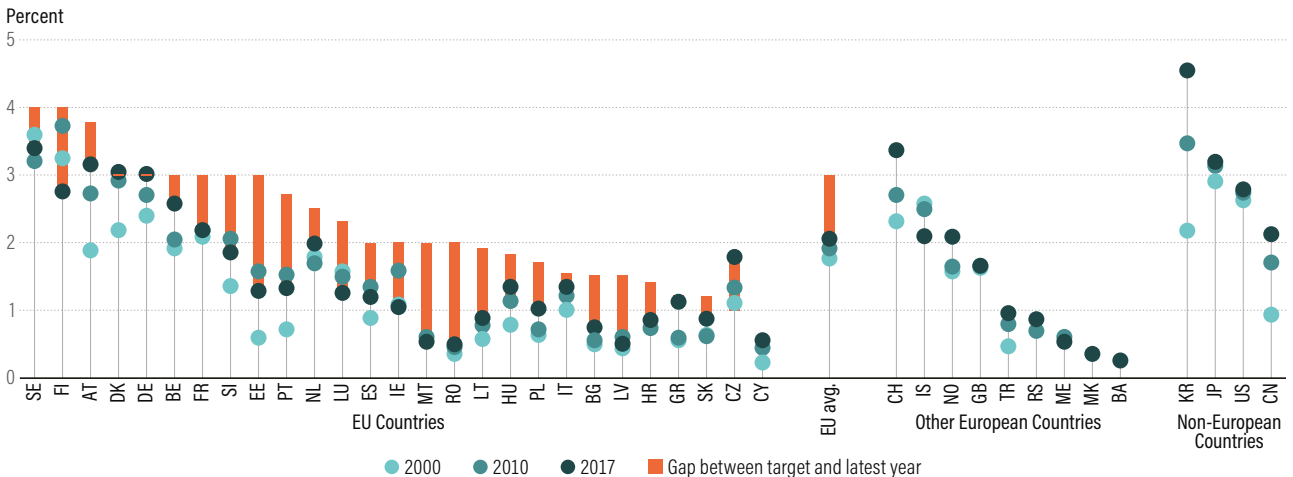
or firms. There are tremendous agglomeration effects for frontier research, and indeed Europe has a handful of true centers of excellence that attract top talent. But those are not the only types of innovation that matter. Supporting technology diffusion, and the adoption of new technologies or applied research, are equally important for expanding opportunities and for raising productivity more broadly. After looking at the level and intensity of R&D efforts, and the distribution of activities across sectors, types of technology and firms, this chapter will turn to technology adoption and diffusion.

Four stylized facts emerge when comparing Europe’s spending on R&D with the United States, China, Japan and the Republic of Korea. First, Europe spends less on R&D as a share of GDP than these other key global competitors. Second, the composition of who carries out the R&D varies, with the private sector accounting for a lower share in Europe and research institutes a higher share. Third, the EU’s efforts are focused on industrial technologies rather than informational or transactional technologies. Fourth, market leaders account for a disproportionately large share of R&D and Europe has relatively few firms within this set. These facts are true for Europe as a whole; this section also makes similar comparisons within Europe to inform recommendations on how to improve the effectiveness of the support to R&D.

### 1. The R&D intensity of most countries in Europe is well below the 3 percent target

The EU has a goal of raising R&D as a share of GDP to 3 percent. This would put Europe more on a par with the United States, China, Japan and the Republic of Korea. Figure 8.1 shows the level of ambition in Europe, and how far many countries still are from their goals on R&D spending. For many countries, this implies an almost 50-percent increase from current levels. As of 2017, only four countries invest 3 percent of GDP in R&D, namely Austria, Denmark, Germany and Sweden. The average is about 2 percent, but this average masks fairly significant variations across countries, from almost 3.5 percent in Finland to less than 0.5 percent in many of the western Balkan countries.

**FIGURE 8.1** R&D intensity falls far below targets in most countries



Source: Eurostat

While there has been some growth in R&D intensity in recent years, significant shifts still need to occur to meet this target. The average R&D rate has only marginally increased since 2000. In several countries the rate has even decreased substantially, from a high base as in the case of Finland, while in others such as Latvia, Estonia, Spain, Lithuania and Portugal the declines are from levels already below the current EU average of 2 percent.

Some of this variation in R&D is appropriate. This is reflected in the differences in the target rates across countries (reported for EU countries). What these numbers do not show — and the numbers are not available — is the breakdown between frontier research and more applied research that can help with diffusion. Cutting-edge R&D will



be concentrated, as limited pools of highly skilled individuals cluster in a few locations. While this work on the frontier may only be feasible in a few locations, diffusing new technologies and helping them to be absorbed and used will still take resources, and these types of investments are needed to support the convergence agenda.

## 2. The private sector is relatively less active in funding R&D in Europe

Beyond the R&D intensity, there are noticeable differences in the composition of who is carrying out the R&D. In particular, the share of R&D performed by the private sector varies. While in most countries the large majority of R&D is carried out by the private sector, the private sector carries out a smaller overall share in Europe than in comparator countries. In Europe, about two-thirds of total R&D investment is made by the private sector and 22 percent by research institutions; in the United States, three-quarters is undertaken by the private sector and 13 percent by research institutions; and in China, enterprises account for more than four-fifths of R&D spending, and research institutions add another 6 percent. Some of the lowest shares are in Europe’s smaller states and lower-income countries.

The share performed by higher educational or research institutions is relatively high on average in Europe, at almost 30 percent. As much of the work by educational and research institutions is funded by the public sector, the proportion funded by governments is relatively high in Europe. Governments’ funding overall is 20 percent in Bulgaria and Slovenia, to over 50 percent in Cyprus, Serbia, North Macedonia, Greece and Montenegro. The average for the EU as a whole is 31.2 percent, which is well above the 25.3 percent in the United States, 23.7 percent in the Rep. of Korea, 21 percent in China and 15 percent in Japan. It also cautions against the public sector doing too much to drive the further increase in R&D. Instead, addressing the incentives facing the private sector to do more R&D has to be part of the agenda. Strengthening the incentives for the private sector to be more innovative will be important in determining competitiveness going forward.

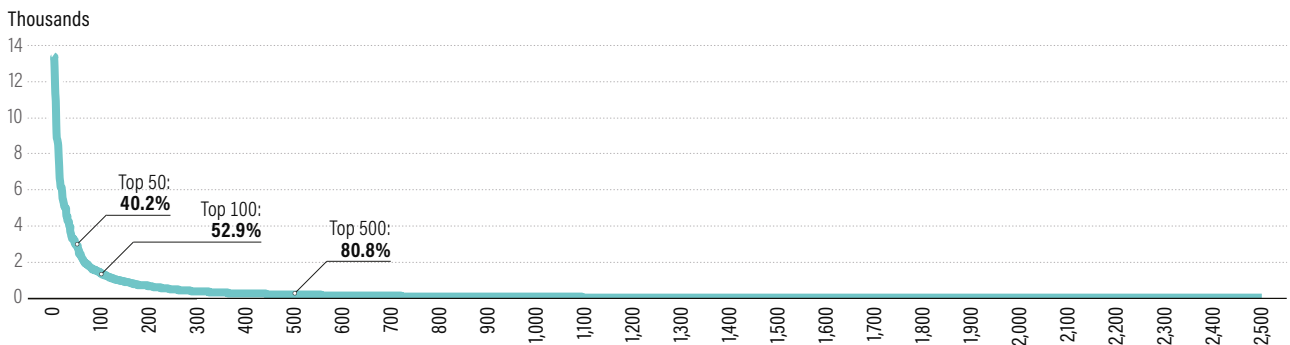
## 3. Firms creating technologies on the frontier are few, but account for a large share of R&D

Within the private sector, investment in R&D is highly concentrated. The top ten companies account for 15 percent of the total and the top 100 do more than half of total R&D spending. Of the top 50 companies that collectively account for 40 percent of the global private sector total, 22 are American, 18 are EU-based, and six are Japanese. The one Korean firm on the list, Samsung, was the top R&D investor at €13.44 billion in 2017, with Alphabet and Volkswagen as the second- and third-largest investors. The only Chinese firm in the top 50 is Huawei, ranked seventh.

Among the top investors, R&D is even more concentrated than sales and employment: the top 1 percent of spenders account for 10 percent of employment, 11 percent of sales, and 32 percent of R&D spending (Figure 8.2). The concentration within Europe is more pronounced for high-tech sectors, but there has been little change over time (Veugelers, 2018).

**FIGURE 8.2** R&D investments are concentrated at the top

Companies ranked by R&D investment, 2018



Source: JRC, 2018.

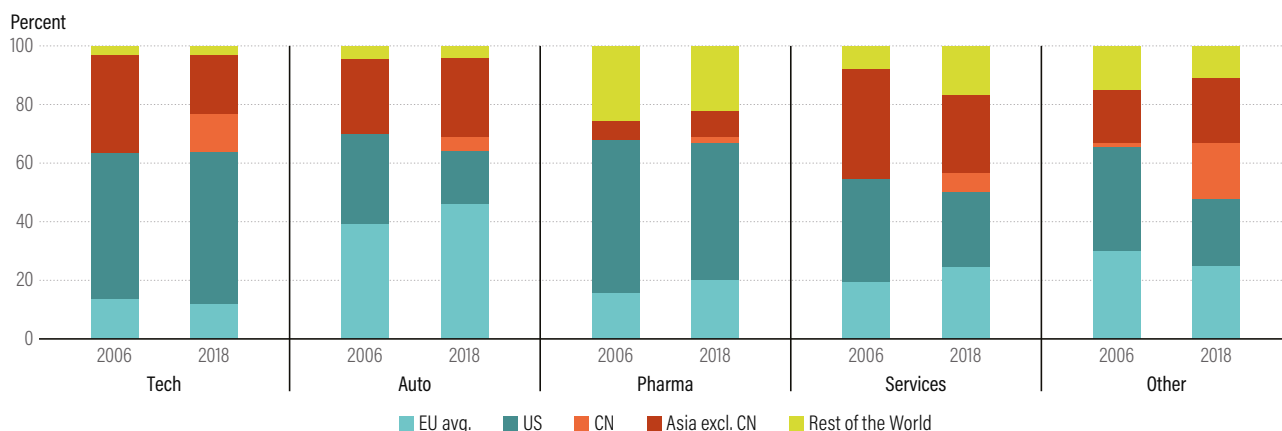
Note: EU = European Union; R&D = research and development.

#### 4. R&D across sectors demonstrates Europe's bet on operational technologies

R&D investments are unevenly spread across sectors, and the patterns differ significantly across regions. Globally, most R&D is focused on ICT, i.e., informational and, to a lesser extent, transactional technologies, and this is where R&D has increased the most. Europe has not been nearly as active as the United States and China. In contrast, Europe has invested far more heavily in operational technologies. In automobiles and batteries—the second most important sector for R&D—Europe is the global leader (Figure 8.3). In pharmaceuticals, the third most important sector for R&D, the United States still dominates.

**FIGURE 8.3** Europe leads the world in automotive R&D, but lags in everything else

Share of R&D expenditures, by sector and country, 2006 and 2018



Source: JRC, 2018.

Note: EU = European Union; R&D = research and development.

### What to do?

#### Criteria for supporting R&D

Box 8.2 summarizes the key financial instruments that support digital innovation and adoption. A full list of initiatives, programs, and policies is included in Annex 6. Simply looking at the amount of money in R&D, or its share in GDP, still misses several dimensions that will matter for competitiveness. How well resources are allocated and how effectively they are spent are critical. The relative balance between creation at the frontier, and the diffusion of technology and applied research, affects the expected impacts on broader measures of competitiveness. Here, the lack of data to be able to analyze these issues is striking. Given the sums at stake and the implications for future performance, greater monitoring and evaluation of these resources should itself be a policy agenda item.

#### BOX 8.2 EU strategies, instruments, and regulations related to digital cohesion

The current primary policy instrument that the EU uses in its approach to cohesion — both across sizes of firms and regions — is the European Structural and Investment Funds (ESIF). The ESIF provide funding through the European Social Fund (ESF) for the development of digital skills and through the European Regional Development Fund (ERDF) for the expansion of broadband infrastructure, as well as support for innovation, the digital economy, and SMEs delivered through a smart

specialization strategy. The Programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises (COSME), another important instrument, supports SMEs' access to finance and markets in the EU and beyond, and strengthens entrepreneurship education and guidance. Importantly, among the EU's primary cohesion instruments there is little focus on improving SMEs' management practices, which is a key enabler for Industry 4.0 technology adoption.

The European Commission has proposed that the EU spends €373 billion in the next program period, 2021–27, on cohesion policy. The Commission proposes to allocate a total of €326.3 billion to the ERDF/ESF+, and the remaining €46.7 billion to the Cohesion Fund. The bulk of European Regional Development Fund will go toward innovation, support to small businesses, digital technologies and industrial modernization. The Cohesion Fund primarily focuses on transportation and environmental issues, which are largely beyond the scope of this report. The Commission is also proposing a new €4 billion Single Market Programme to empower and protect consumers, and enable Europe's SMEs to take full advantage of a well-functioning single market. An additional €2 billion allocated under the InvestEU Fund, in particular through its SME Window, will contribute significantly to the inclusion objectives of the Single Market Programme.

**The Digital Innovation Hubs (DIHs)** — an initiative of the digital single market — is a pan-European network of one-stop shops where companies, especially SMEs, can get help to improve their business and production processes, and products and services, by means of digital technology. The EU supports the collaboration of DIHs to create an EU-wide network, where companies can access competences and facilities not available in the DIH in their own region; for this, the European Commission launched the European catalogue of DIHs. This network will lead to knowledge transfer between regions, and will be the basis for economies of scale and investments in the hubs. For this, the Commission is investing €100 million per year from 2016 to 2020. More initiatives on DIHs have been supported from 2018 to 2020, with a total investment of €300 million within the Horizon 2020 Programme.

**European Structural and Investment Funds (ESIF): The European Social Fund (ESF)** is Europe's main instrument for supporting jobs and

*Source: Europe 4.0 team compilation.*

entrepreneurship, with financing of €10 billion a year and a priority to boost the adaptability of workers with new skills, and enterprises with new ways of working.

**EU Programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises (COSME):** COSME aims to make it easier for SMEs to access finance and markets in the EU and beyond, and supports entrepreneurs by strengthening entrepreneurship education, mentoring, guidance and other support services. COSME also aims to improve business conditions in the EU by reducing administrative and regulatory burdens on SMEs. The program runs from 2014 to 2020 with a planned budget of €2.3 billion.

**I4MS, ICT Innovation for Manufacturing SMEs:** I4MS is a European initiative supporting manufacturing SMEs and mid-caps in the widespread use of ICT in their business operations. Under I4MS, SMEs can apply for technological and financial support to conduct small experiments, allowing them to test digital innovations in their business via open calls. The I4MS initiative is currently in its third phase, which started in September 2017 with a budget of €34 million.

**The "Smart Anything Everywhere":** An initiative of the European Commission, under Horizon 2020, offers funding and support to SMEs to upgrade their products and services to the digital age. This is a key initiative of the Digital Innovation Initiative to help build the DIH network and boost innovation.

**Member states' state aid to advance the digital economy:** Public support under EU state aid rules has been an invaluable alternative to projects where associated higher risks have deterred private initiatives supporting innovation. Member states can also jointly finance Important Project of Common European Interest (IPCEI) pending the Commission's assessment under the IPCEI Communication.

Three criteria are important. First, where the need is greatest. But second, this must be filtered by where resources can be most effectively used. And third, the process for these evaluations matters; feedback loops between the investments and outputs, informed by technical experts, can be important not only in updating these decisions for efficiency but also for transparency and public support. The section above has identified where the gaps are, while the sections below look at the effectiveness of spending and the process for making decisions.

In terms of policy recommendations, there are three that stand out from this analysis in terms of how to allocate resources:

### **Allocate R&D based on the effective use of R&D resources**

While equalizing R&D across locations and firms should not be the goal, the effective use of resources has to be one criterion. Looking at how R&D investments translate into outputs should be one criterion for determining the allocation of resources. Unfortunately, this is not a straightforward calculation. Breakthroughs can be lumpy and unexpected rather than incremental and consistent. It is not always easy to predict how close success may be, or whether a breakthrough will translate into commercial success. However, on its own technical terms, experts can help evaluate the rigor of approaches and the soundness of the decisions taken that can inform the next round of funding.

Citations in top journals and patents are two common ways to evaluate the effectiveness of R&D inputs. However, they are not the only outcomes of interest. And they do not necessarily indicate the extent of a breakthrough or its commercial value. To the extent possible, it is important to control for quality; quantity on its own may be misleading as to the true extent of innovation if all the changes are very incremental. Restricting publications to the top scientific publications and looking at the extent of citations in other patents can help control for quality, but it is at best only a proxy. There can also be a considerable disconnect between where a discovery is made and where the patent is filed. Not surprisingly, far more patents are filed in tax-friendly locations than are discovered there.

The EU's share of scientific publications is 27.1 percent, more than the United States at 19.5 percent or China at 16.7 percent. However, when looking at the top 1.0 percent of highly cited scientific publications, the EU's share is 32.2 percent, the United States' share is 35.1 percent and China's share is 9.4 percent. This would seem encouraging; the EU's share of top publications is higher than its global share of R&D investments.

In terms of PCT patents (normalized per billion of GDP), Japan stands out as having the most—almost triple the number compared with the United States or the EU. Within Europe, Sweden ranks top, followed by Finland, then Germany, Denmark, the Netherlands, Austria and France. The rest of the member states are below the EU average. There is of course variation across the types of technologies. Given that AI, as a general purpose technology, underlies how data insights are being used across a wide set of applications, patterns on AI patents are of particular interest. In the period 2000–05, the EU accounted for 19 percent of IPS patents, but by 2010–15, this had dropped to just under 12 percent. The United States and Japan similarly declined. China and the Rep. of Korea, on the other hand, expanded their shares, from 1.7 to 10.4 percent, and from 10.5 to 17.5 percent, respectfully. Within the EU, Germany leads the way, followed by France, the United Kingdom, Sweden, Finland and the Netherlands.

### **Build in feedback loops to monitor and review funding decisions over time**

Third, having monitoring and evaluation systems in place can provide important feedback on how well programs are operating. It can take time for R&D to result in commercial outputs. But expert evaluators should be able to determine the likely feasibility of the projects and how well progress is or is not being made. Currently, too many large blocks of funding are allocated without such an ongoing and repeated review process.

#### **BOX 8.3** Learning from Horizon 2020 for Horizon Europe

Within the EU, Horizon 2020 has been a key program to support innovation across Europe. Horizon 2020 accounts for less than 10 percent of R&D funds, with rates higher in smaller and lower-income countries. In terms of absolute amounts, the allocation looks different, with substantially more going to subnational regions where there is a concentration of R&D activities (Map B8.3.1). Comparing the allocation of overall Horizon 2020's support with the distribution of funding for transactional, informational and operational technologies, the differences are fairly subtle. Digital technology research hubs are largely in the same places as R&D has traditionally been carried out.

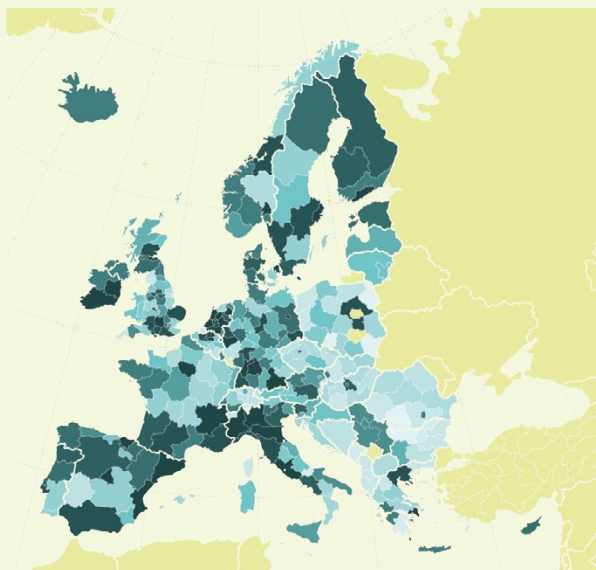
Horizon 2020 is now in its final stages, and the proposed new Horizon Europe received preliminary approval in April 2019 and will start in January 2021. The initial expected budget envelop is just under €100 billion. The program has three pillars. The Open Science pillar (€25.8 billion) would continue to focus on breakthroughs in science. The second pillar (€52.7 billion) is allocated to Global Challenges and European Industrial Competitiveness. Under Horizon 2020, almost two-thirds also went

to the former and one-third to the latter, so this would continue the same relative priorities. The remaining €13.5 billion would support the third pillar and market-creating innovation via the European Innovation Council. It would become a one-stop shop for innovators, providing support for projects that are too risky for private investors. Seventy percent of the budget is likely to be earmarked for SMEs.

In moving from Horizon 2020 to Horizon Europe there are opportunities for improvement. First, ensuring there is sufficient investment in expanding opportunities for new markets is one area for improvement. One of the key lessons is to strengthen and have dedicated support, financial but also advisory, on how to translate innovation into commercial success. This is particularly important in supporting the inclusion objective.

Second, another priority is in improving the process by rationalizing the financing decisions and expanding opportunities for partnerships—importantly including international partnership. Expanding the commitment to open research would also be aligned with this, and would reinforce Europe's mission-based approach and interest in

**MAP B8.3.1** Horizon 2020 allocations



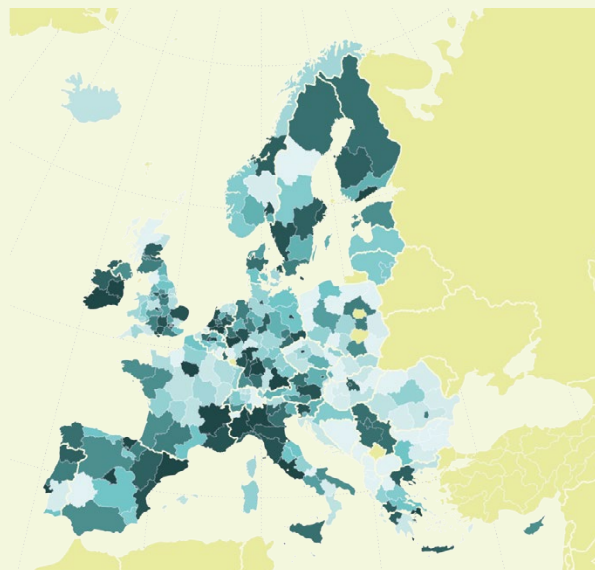
Source: Ciffolilli, Muscio and Reid, 2019.

setting international standards. Expanding partnerships would reinforce the convergence objective.

Finally, there is already a fair amount of citizen involvement in setting priorities for the allocation of mission-driven R&D. This should continue.

Source: Eurostat and DG RTD 2019 and Ciffolilli, Muscio and Reid, 2019..

**MAP B8.3.2** Horizon 2020 Industry 4.0 allocations



Source: Ciffolilli, Muscio and Reid, 2019.

Given that some areas are changing rapidly and, as the role for data within a wider set of activities is accelerating, having informed citizen outreach is important in building trust on how innovation in Europe can contribute toward desirable human-centric solutions

## Agglomeration economies in innovation: hubs of excellence over plains of mediocrity

### What is at stake?

As stressed in the introduction, equalizing R&D across all locations is not the goal. This is all the more true when looking at NUTS2 levels of R&D rather than country levels. There are strong agglomeration economies in innovation, so some concentration of frontier research is desirable. But there are still dynamics here; new centers can emerge. Indeed, looking at the top 20 innovation hubs in Europe, two are in Poland and one is in the Czech Republic. Importantly, centers of excellence should be seen as connected hubs rather than islands of excellence if more firms and locations are to benefit from the diffusion of new technologies.

Research and industry clusters for digital technologies are largely concentrated in leading regions, such as the Paris metro area and Bavaria. However, several pockets of digital technology excellence have formed outside of northern and western Europe, including in Madrid, northern Italy, and Warsaw, with allocations of Horizon 2020 funds going disproportionately to them (Map B8.3.1). The funding for technologies associated with advanced digital technologies largely follow the same pattern, although if anything they are even more concentrated (Ciffolilli, Muscio and Reid, 2019).

Given the large sums of money at stake, there is an important question of whether resources should be used to spread out expertise and the ability to innovate across more regions. The risk is that, rather than hubs of excellence, they become islands of excellence—or islands of limited excellence. Efforts to build new innovation hubs



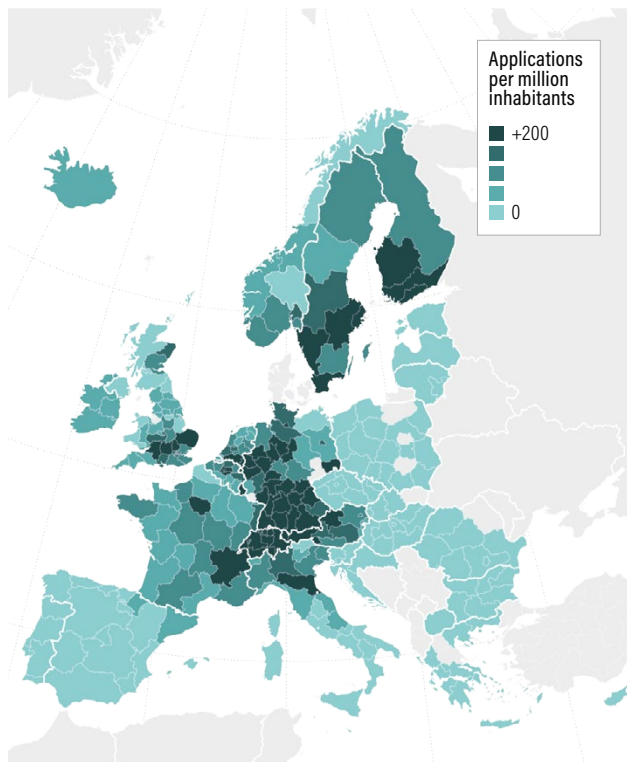
in lagging regions through Smart Specialization create small clusters of research institutions operating at various levels of performance, but all too often unconnected to the surrounding industry base or larger research community (Radosevic, 2019).

Complete convergence in innovation across member states and regions is not a realistic proposition; regions will inevitably innovate and adopt technologies at different speeds. Spatial disparities are inherent to the innovation process, and new digital technologies are no exception (see Map 8.1 on patterns of patenting). Innovative activity relies on the agglomeration effects of the skilled labor supply and knowledge spillovers, and these effects have positive feedback relationships even at the firm level (Carlino and Kerr, 2014). These agglomeration gains accrue in highly developed regions. What is critical is whether these dynamics come at the expense of less competitive regions or can be accomplished in a way that serves other more lagging regions too. This is at the heart of the next policy section below on whether convergence happens automatically or not.

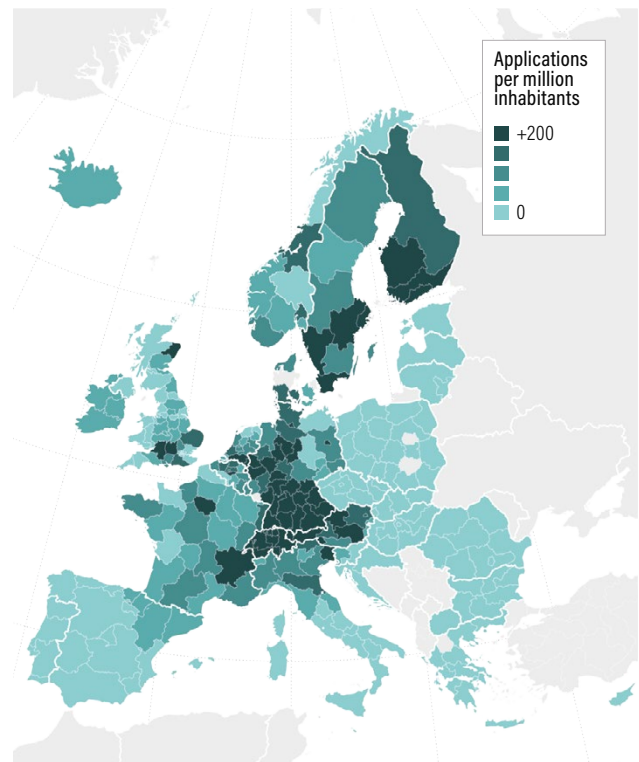
### MAP 8.1 Patent applications to the European Patent Office

By priority year (per million inhabitants)

a. 2001



b. 2012



Source: Europe 4.0 team, based on Eurostat.

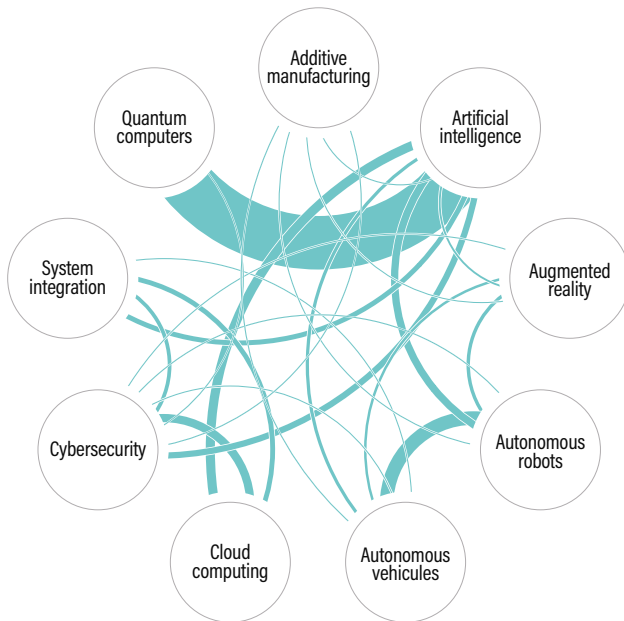
#### Prior capabilities matter in predicting the future likelihood of successful innovation in a location

Balland and Boschma (2019) offer insights using patent data to understand the likelihood that a given location is well positioned to achieve new patents in a new area. They use the patterns of patents and their citations by sector and location to determine associations and the relatedness of strengths in one area being likely to make breakthroughs in other areas possible (Figure 8.4). It is not a causal analysis, but the associations do show common patterns where certain types of technologies are more likely to be needed to reach certain others; some seem to serve as building blocks, or are more accessible than others. This type of information can also help to identify what is likely to be feasible ex ante.

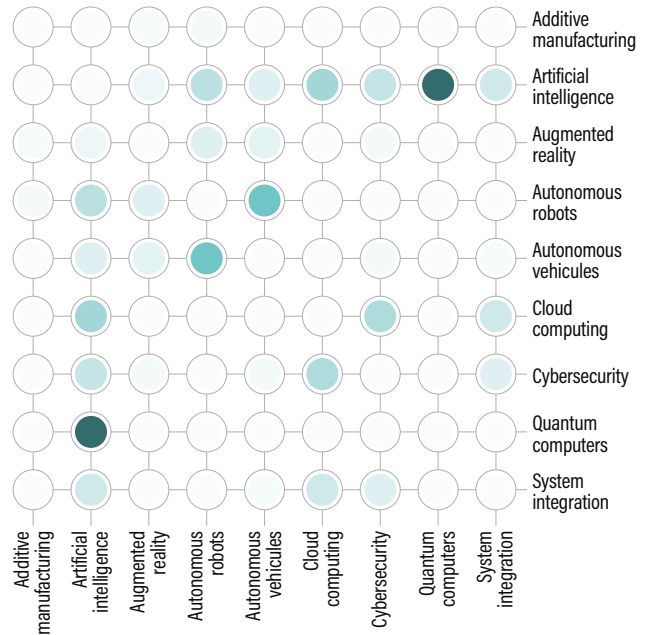


**FIGURE 8.4** Relatedness of Industry 4.0 technologies

a. Illustrated by connectedness map



b. Illustrated in matrix



Source: Balland and Boschma, 2019.

Using these empirical patterns of where new patterns build on earlier patterns in the same location, NUTS2 across Europe can be plotted with how related their technological innovations are. The more related areas tend to have many more areas of expertise where patents are filed.

Regions in Germany, France and the United Kingdom showed high potential for developing data-driven digital technologies, largely by drawing on resources from related technologies available at the regional scale. There are a few in other EU countries and regions, but the data point to more limited capabilities to draw on in being able to master new areas of technology. This approach cautions against optimistic bets on ‘leapfrogging’; the patent data show greater success where investments build and expand on existing capabilities.

### Most locations will specialize; only a few master multiple technologies

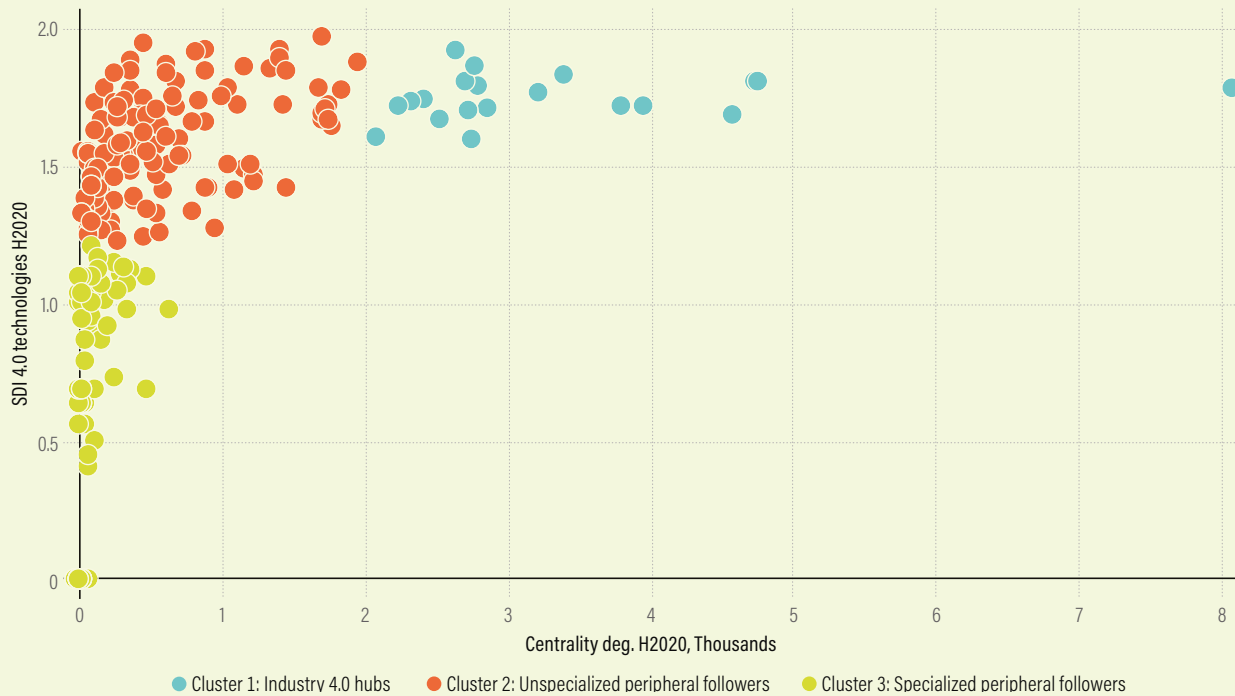
The goal cannot be to do all things in all places. Looking at NUTS2 data, there are about a dozen that stand out as mastering a wide range of technologies (see Box 8.3 and Box 8.4). There is a middle group that is following, with expertise in multiple areas, and then many more areas that are making progress on a small set of technologies. Strikingly, the degree of complexity of technologies mastered is strongly linked with how networked the location is with researchers and with the private sector, including across multiple locations. This underscores that R&D should not be understood in isolation; links to other areas of expertise and to firms that can commercialize the research are critical (Ciffolilli, Muscio and Reid, 2019).

### Links to markets also affect adoption

Comparisons of R&D inputs and outputs provide only a partial picture of regional digital technology creation and adoption capacity. Regional production capabilities, which are more relevant for lagging regions, can also play a role in the development and adoption of data-driven Industry 4.0 technologies. In an assessment of Central and Eastern European economies, for example, Radosevic (2017) concludes that lagging economies do not take full advantage of research-driven innovation because they lack the technological capabilities needed

**BOX 8.4** Only a few NUTS2 regions stand out as technologically sophisticated and regionally networked

**FIGURE B8.4.1** Industry 4.0 hubs



Source: Background paper by Ciffolilli, Muscio and Reid, 2019.

Note: H2020 = Horizon 2020; NUTS = Nomenclature of Territorial Units for Statistics; SDI = Shannon Diversity Index (SDI).

**Industry 4.0 hubs (cluster 1).** This is a group of 20 regions, five of which are located in Germany, that enjoy multiple and strong links to many other regions in a relatively wide range of enabling technologies, and with competitive companies and research institutions. They can be considered as hubs of genuinely wide inter-regional systems of technological cooperation. These clusters receive a large share of funding both in Horizon 2020 and FP7. They are also characterized by a higher participation of the private sector.

**Unspecialized peripheral followers (cluster 2).** This group includes a large number of regions (144) that are less central in research networks and do not specialize in any Industry 4.0 technology in particular but, nonetheless, they participate in R&D projects financed by the EU and have the potential to establish connections to European hubs. Nearly one-third of these regions are located in Germany, Italy, Spain and the United Kingdom. Their technological activities are very diverse.

Source: Background paper for this report by Ciffolilli, Muscio and Reid, 2019.

**Specialized peripheral followers (cluster 3).** This is a relatively large cluster of 100 regions that, as in cluster 2, are less central in networks but specialize in just some Industry 4.0 technologies. Their technological activities are more limited and less diverse than in the Industry 4.0 hubs, while their regional innovation systems are less competitive. However, even though their capacity to differentiate research and innovation activities has shrunk over the years, they seem increasingly capable of establishing effective links with other regions, when taking into account the quality of the connections (Scherngell and Barber, 2011) and estimated by the centrality of their partners (Bonacich, 1987).

**Isolated systems (not shown in the graph).** This group includes 29 regions, about 10 percent of the total, which did not participate in any Horizon 2020 projects focused on Industry 4.0 technologies. Therefore, while a range of opportunities for collaboration in technology development may exist at the national level, interregional cooperation needs to be leveraged.

to take advantage of R&D investments. These include the ability of firms to adopt and adapt imported industrial technologies and inputs, the adoption of quality standards and certification, and the alignment of local R&D investments with technology-oriented foreign direct investment. Production and technological capability are likely to be the most significant drivers of productivity growth in lagging regions, compared with R&D and research-driven growth in leading or advanced regions.

## What to do?

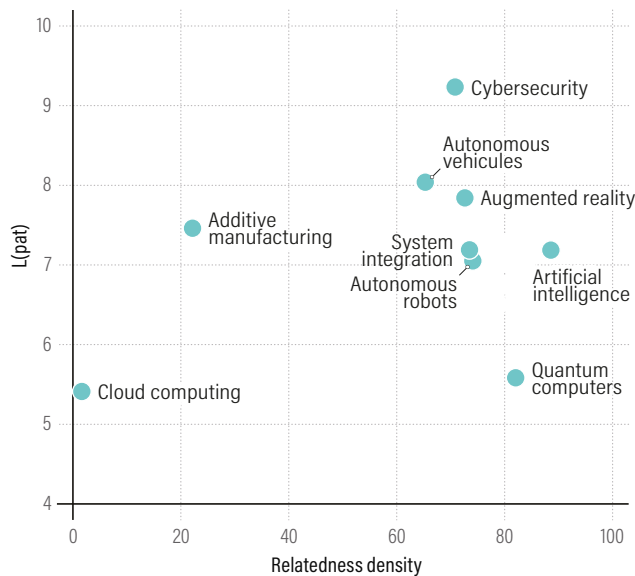
### Take prior capabilities in related technologies into account in funding decisions

It is appropriate the funding for frontier research is concentrated in centers of excellence that have expertise in multiple technologies, making it that much more possible to be innovative. Given how few locations are able to have innovations (as measured by patents) without also having demonstrated expertise in the underlying rungs in the technology ladder, having high expectations for a given technology outside centers of excellence is unlikely to be effective.

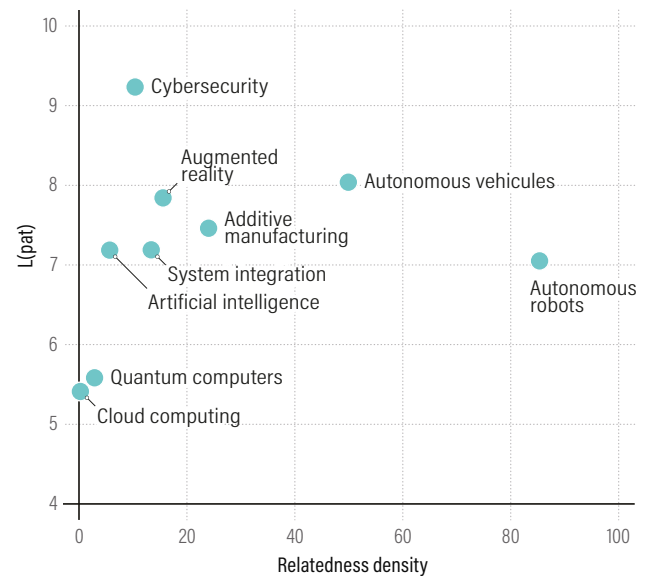
Balland and Boschma's (2019) relatedness approach can be used to look at individual NUTS2 regions and the types of technologies they have and how many of the "precursor" technologies associated with it have patents in that region (Figure 8.5).

**FIGURE 8.5** Mapping of Industry 4.0 technology opportunities

a. Île-de-France, France



b. Piedmont, Italy



Source: Balland and Boschma, 2019.

The relatedness density for several technologies associated with Industry 4.0 is shown in Figure 8.5. It also shows how, for a particular region, the relatedness of patents is associated with total patents in any given technology in Europe (i.e., the y axis is the same for both). The message is that the Île de France has relatively low potential in cloud computing and additive manufacturing based on its low relatedness density, but performs well on the other seven technologies. Piedmont, in contrast, stands out for automation and robots, and somewhat on autonomous vehicles, but otherwise has relatively low preparedness for the other technologies (Balland and Boschma, 2019). Similar calculations could be made for all the NUTS2 in Europe.

### Build 'hubs' not 'islands' of excellence

Regions do build up expertise over time and this expertise is then increasingly networked across multiple locations. This expands the externalities associated with the centers of excellence in ways that contribute to diffusion. For lagging regions, getting linked into these networks, rather than necessarily trying to be the hub itself, is a way to strengthen expertise and access to knowledge to build up the potential for innovative activities. This links this innovation agenda with the question of broader diffusion and how well technology spreads automatically. The more connections there are, the more effective the diffusion results.

Partnerships between the private sector and dedicated research centers or centers for higher education play an important role in both demand for innovation and its creation. Within Europe, some of these partnerships cross borders, taking advantage of synergies across locations within Europe. Much of the work on AI has clustered around London and Paris, while much of the work on autonomous vehicles and batteries is in Germany. For Europe, the debates over Brexit put a particular focus on the recommendations regarding international cooperation to achieve innovation breakthroughs. R&D is already fairly strongly networked across the top centers in the EU. Having a framework for collaboration in R&D should be a priority in post-Brexit negotiations.

### BOX 8.5 The performance of Balkan countries in building centers of excellence

Comparing countries in the Western and Eastern Balkans underscores that, while they generally lag behind the Northern and Central European countries in their use of digital technologies, there is important variation across countries and across technologies. While none of these countries is strong across all digital technologies, some are strong in a few of them and are investing to build on these emerging strengths.

Data on patents show clusters of innovation within the Balkan countries within specific types of technologies, where they are the leading locations in Europe. Serbia's Novi Sad and Romania's Cluj have nascent

digital clusters. Bulgaria's region, which includes the capital Sofia, demonstrates considerable potential in augmented reality (top ten of all European regions), as well as capabilities in cybersecurity and some operational technologies, such as additive manufacturing and autonomous vehicles. Several regions in Romania also demonstrate capabilities in cybersecurity and operational technologies based on the Horizon 2020 funding they received. North Macedonia is investing in Augmented Reality, and Montenegro shows a moderate advantage in Simulation, as well as Augmented Reality.

## NATIONAL LEVEL: ADDRESS DETERMINANTS OF TECHNOLOGY ADOPTION

The focus at national and subnational levels should be on supporting firms' capabilities to accelerate the diffusion of operational technologies. This involves balancing national innovation budgets between supporting frontier research and more applied research. It includes support for developing innovation hubs in sectors of relative strength, as well as developing new applications for operational technologies in traditional sectors. It means working with firms to strengthen their capabilities to absorb technologies and manage internal change processes to use them successfully. And to be successful, it also involves tailoring the choice of instruments and types of programs to the capacities of local governments to implement them.

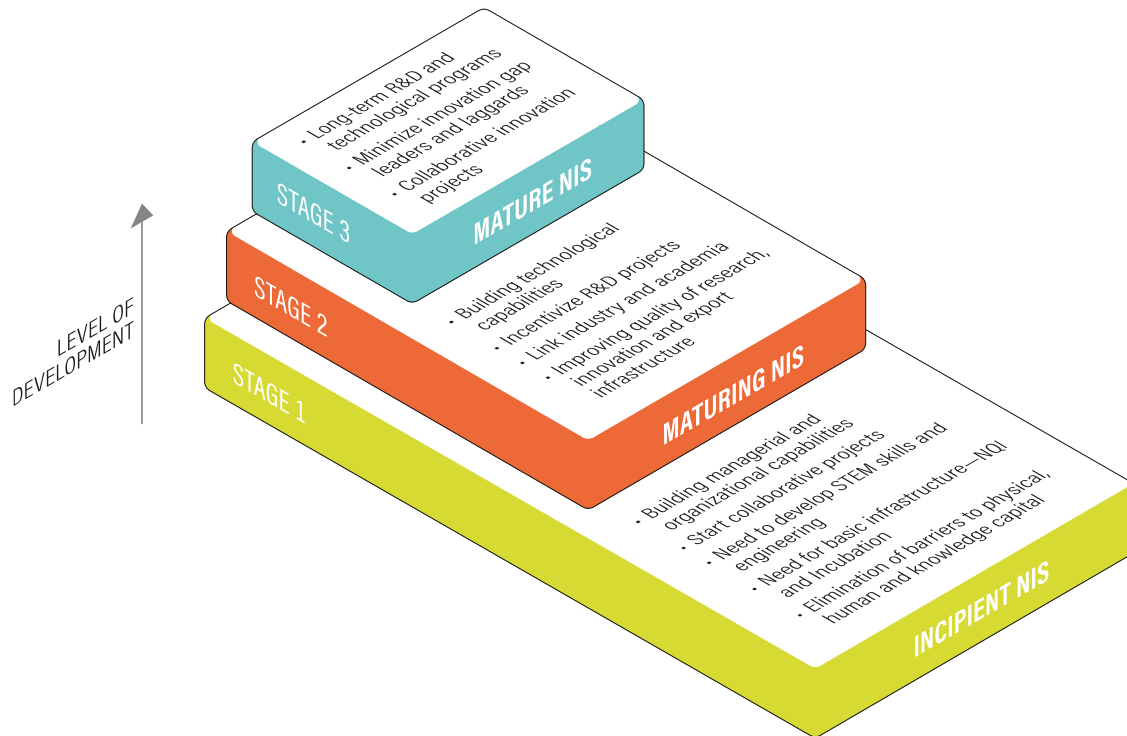
### Adapting innovation strategies to the local context

#### What is at stake?

The Commission, through its structural and cohesion funds, can aid member states and regions to ensure that their SME digitization policies, regulations, and incentives are appropriate for the country context. This can be accomplished through the capabilities escalator approach,<sup>1</sup> which aligns policy support instruments and associated public resources with the specific firms' capability needs of a given economy, as shown in Figure 8.6 (Cirera and Maloney, 2017).

While leading regions might have SMEs that benefit from R&D support, and incentives to develop and adopt more cutting-edge advanced manufacturing technologies and digital-physical infrastructure, SMEs in lagging regions likely lack the basic capabilities and resources to make use of such support. Recent efforts by the

**FIGURE 8.6** National innovation system capabilities escalator



Source: Cirera and Maloney, 2017.

Commission to align the different structural and cohesion funds with the digital agenda, and increase the allocation to digitization initiatives, are steps in this direction. However, some areas, such as building SMEs' managerial capabilities, could and should be better addressed (see Box 8.6).

**BOX 8.6** Analytical underpinnings for a digitally fit policy mix: Cases from the Czech Republic, Croatia and Poland

The World Bank, in collaboration with the European Commission and national governments, has performed several in-depth analyses of government programs that support research and innovation (Croatia, Poland) or SMEs (the Czech Republic) using an analytical framework that compares the existing national policy mix with the country's needs (the World Bank Public Expenditure Review of Science, Technology, and Innovation). These analyses identified gaps in certain areas, such as improving management capabilities and the adoption of key Industry 4.0 technologies (big data, automation, etc.) to catch up with more productive firms. These assessments concluded with a series of recommendations aimed at improving the policy mixes for the digital age, including policies conducive for the diffusion of operational technologies. These included:

- Helping to identify technology and digitization needs depending on SME/firm type through intensive outreach, data-focused competitions, diagnostic tools (including self-diagnostics), and technology extension services.

- Building managerial capabilities in SMEs that can leverage productivity-improving technologies through support for external management services, consultancies, and the adoption of international quality standards.
- Strengthening linkages between SMEs, and foreign and large firms, by establishing supplier development programs to help SMEs meet the higher value-added production requirements of foreign firms and incentivizing multinationals to locate innovation activities in the country.
- Improving SME-academia collaboration through financial incentives for collaborative research, pilots, feasibility studies, and technology transfer activities.
- Introducing regional proof-of-concept (PoC) programs to provide financial support to technological projects with commercialization potential and of regional significance, that were not selected for funding in EU or national programs

Source: Authors based on Aridi and Lopez, 2019, Croatia and Poland Public Expenditure Reviews on Science, Technology, and Innovation (PER STI).

## What to do?

The innovation agenda needs to be adapted to the local context. This includes integrating innovation efforts with the local economy, and building local institutions to effectively support firms. The extent of local firms' capabilities also matters, as discussed in the next section on choosing the right policy instruments.

### 1. Focus on sectoral application and integration in lagging regions

The first part of this chapter has focused more on frontier R&D. However, operational technologies can also present opportunities for lagging regions through applied R&D activities, and sector-specific applications and integration (Perez, 2010, 12; Bresnahan and Trajtenberg, 2008). The applied dimension offers an opportunity for secondary regions to contribute to technology development. This is a process where leading regions invest in the invention and advancement of these technologies, while catching-up regions may have a role in the development of the applications and integration of digital technologies into key sectors of their regional economies.

This application and integration role presents an opportunity for secondary regions to allocate their research investments to more competitive, demand-driven applied R&D projects in areas relevant to the local industry mix. It is important to note that different sectors have different propensities toward the adoption of digital solutions. The automotive sector is a leader, but a number of manufacturing processes can use smart automation. The expansion of industrial IoT implies many more ways that these technologies will be used and developed.

The applied research and sectoral focus will require a shift in funding priorities in catching-up countries and regions, particularly in former Eastern bloc countries, moving away from bloc institutional funding of basic R&D (typically conducted by national academies of science and public research institutions), toward more competitive applied R&D projects, ideally driven by demand from local private players. Additional support for sectoral integration might include the facilitation of matchmaking between technology providers and potential adopters, and training and sector-specific digital skills acquisition.

Links to local markets provide greater feedback loops on what is demanded and whether efforts to raise productivity through technology adoption are being effective or not. However, given that there are market failures in information, financing and coordination, there can still be a role for government programs to support firms in this process. The key to the success of many of these efforts will be the capacity of the local implementing organizations, and their ability to deploy resources and sunset programs based on feedback loops imbedded into the design of these pilots.

The COVID-19 pandemic and its potential disruptions on value chains raise the prospect for greater reshoring, including possibly to lagging regions within Europe. While the extent is contested (Baldwin and Tomiura, 2020), it is also true that accelerating the automation trends is likely. Supporting more firms to adopt operational technologies offers the potential to maintain operations, safely and with fewer disruptions (see Box 8.7).

#### BOX 8.7 The COVID-19 effect on automation and reshoring

The COVID-19 pandemic has exposed the vulnerabilities of global value chains (GVCs), which are characterized by high interdependencies between firms fragmented across the globe (Seric and Winkler, 2020). Many countries are currently facing supply shortages of medical equipment and other critical intermediate inputs, particularly from China (Baldwin and Tomiura, 2020). Therefore, even at current levels of automation, the current crisis may spur reshoring in GVCs to high-wage economies. If lead firms place a premium on reducing uncertainty, the use of robots in high-wage economies can consolidate various steps of the value chain in major consumer markets such as the EU, even if their

cost currently exceeds that of low-skilled labor in lower-wage countries. This automation and reshoring allow for more flexible adjustment, thereby mitigating firms' risks in the event of demand or supply shocks, such as with the COVID-19 pandemic (Seric and Winkler, 2020).

Furthermore, there might also be a surge in automation during economic crises, laying the ground for greater reshoring in the future. As labor becomes relatively more expensive when firms' revenues decline with an economic shock, managers replace less-skilled workers with machines, which increases labor productivity as a recession tapers off (Muro, Maxim and Whiton, 2020). This cyclical nature of automation has been previously



emphasized. Evidence from the United States suggests that “routine” automatable occupations accounted for 90 percent of job losses over three recessions in the past 30 years (Jaimovich and Siu, 2020). Similarly, analyzing almost 100 million online job postings before and after the global financial recession, Hershbein and Kahn (2018) found that firms in hard-hit metro areas were steadily automating workers in “routine” tasks.

At the same time, reshoring of production is not a prerequisite to ensure the supply of medical equipment and other critical goods. In fact, it is unlikely that entire supply chains can feasibly be automated and drastically altered in the short term. The case for reducing the concentration of globally fragmented production among firms in China may therefore be fulfilled by shifting supplier bases to other low-wage labor-intensive economies. Such a shift in sourcing patterns away from China to other economies in Asia will reinforce a trend initiated by the United States-China trade wars. In a recent survey of the ‘United States Fashion Industry Association’ conducted before the COVID-19 pandemic, 84

percent of buyers expected a decline in sourcing from China in the next two years. Vietnam, Mexico, and Taiwan, China, have already benefited from such trade diversion (Nicita, 2019).

There might also be greater automation in low- and middle-income countries if robots can enable factories to adapt to post-COVID-19 workplace arrangements by emphasizing physical spacing between employees on assembly lines. For example, a highly automated chip company in Wuhan, China, kept operating through the lockdown (The Economist, April 8, 2020). Such automation reinforces the current structure of GVCs and has been seen even before COVID-19. For example, Ford Motor Company’s highly automated 460-acre facility in Gujarat, India, that churns out 240,000 vehicles and 270,000 engines a year looks very similar to what one might see in North America or Europe. Similarly, Adidas recently announced that its automated production lines in Germany and the United States will be moved to China and Vietnam, where 90 percent of Adidas’ suppliers are currently located.

## 2. Build capacity for national and regional institutions setting the technology agenda

In addition to policy instruments and initiatives, innovation agencies are increasingly playing an important role in diffusing technology and helping more firms move to the frontier. While not required, if well designed, managed and funded, innovation agencies can make a real difference in promoting innovation. Importantly, their role should not just be focused on pushing the frontier; they are often more effective with applied research. Given the large productivity gains from catching up — and demonstrable evidence that this often does not happen automatically — such agencies can help address market failures to facilitate innovation.

A recent analysis of the experiences of 13 innovation agencies from developing countries presents seven building blocks as pre-requisites for the success of innovation agencies including: a clear but adaptable mission; capable staff; effective governance and management structures; diagnostic-based interventions; robust monitoring and evaluation (M&E); sustainable funding; and strategic partnerships and networks (Aridi and Kapil, 2019). Building the capabilities of these national and subnational organizations to deliver outcomes will become increasingly important for the support of digital deployment and dissemination.

The governance arrangements of innovation agencies are worth underscoring. Having some independence of professional experts involved in decision-making is desirable, but with sufficient transparency and oversight that is appropriate for a public institution. Having some independence in the technical recommendations can also be helpful in mitigating some of the purely political considerations from driving decisions. The role of the National Science Foundation or National Institutes of Health in the US in allocating money is one such model, while the European Commission’s Horizon 2020 similarly relies on broad consultations in setting the overall priorities but with experts choosing specific research agendas to fund. Having explicit and realistic objectives, logical frameworks, and M&E indicators helps to justify the policy interventions and allows for adjustments, expansions or termination in implementation based on the feedback of what works.

## Take seriously challenges to technology adoption at the firms’ level

### What is at stake?

As discussed in the introduction, smaller firms face greater challenges in absorbing new technologies, particularly operational technologies that require higher skills or greater reorganization of how they do business. But there is a spatial dimension reflecting the links to innovation (including applied) hubs and markets, and

expanding the geographic reach of where operational technologies can successfully be used. There will always be agglomeration economies that favor some concentration of activities, but the evidence underscores that new centers can emerge, albeit incrementally.

The barriers to adopting the newer operational technologies can be significant. These entail high fixed costs that are likely to benefit larger enterprises with larger resources available. They also disrupt the internal operations of firms, such that the ability of firms to use them is determined in part by internal-to-the-firm factors, including managerial and technological capacity, change-management capacity, and the availability of the appropriate skills.

Chapters 4 and 5 show how firms' size matters in the adoption of digital technologies. While small firms may make smaller investments in easy-to-use digital upgrades such as cloud computing or CRM software, they struggle to adopt process-transforming operational technologies. Similarly, in an analysis of the impacts of new technologies on German firms, Sommer (2015) finds that the smaller firms are, the higher the risk that they are unable to adopt new technologies and that they become increasingly less productive relative to their competitors. Moeuf et al. (2018) find that SMEs often limit their technology adoption to cost-driven upgrades, such as using cloud computing instead of physical servers, and do not take advantage of the full potential of such technologies to transform company processes. Cirera et al. (2015) argue that technology adoption by SMEs requires a range of complementary factors, including those internal to firms' capabilities (such as management, organizational, and marketing skills) and those external to firms' factors (such as infrastructure and an enabling business environment).

The internal-to-firm enabling factors for operational technology adoption vary greatly by firms' size, whereby SMEs are usually at a disadvantage:

- **Change management capacity:** Operational technologies can enable new business models and process changes, but adopters need to have the capacity and willingness to make these dramatic changes to their businesses and processes. Bigger firms usually already have the resources and vision to embark upon such changes. Nevertheless, smaller firms with visionary management can better position themselves, and leverage their nimbleness and agility.
- **Ability to integrate into production processes:** If the installation and integration of a new operational technology creates a disruption to company operations and production schedules, it can create a major challenge and disincentive for adoption. SMEs, in particular, are largely driven by tight production timelines and short planning horizons, and they rarely have the time or resources for the sourcing and implementation of new operational technologies.
- **Data management capabilities:** Even for operational technologies, data management is a necessity to the adoption and use of the technology. Companies need to know what their internal data challenges are, and need to be able to collect, clean, and manage their own data for these to be useful. This often presents a challenge for implementing data-reliant operational technologies. Large firms tend to have better data-tracking and management practices in place.
- **Internal stock of digital skills:** Potential adopters need to recruit and retain workers with data management and analytics skills to implement and utilize data-intensive operational solutions. SMEs are usually at a disadvantage when competing for scarce digital talent with larger and resource-endowed firms.
- **Knowledge of potential operational technology solutions:** SMEs often do not have the same access to information about potential operational technology solutions and how they could improve their businesses as larger firms (Aridi and Querejazu, 2019).

Geographically, connecting innovation hubs to markets, and building on existing capabilities are important in raising the level of sophistication of production in a wider set of locations. In allocating resources for innovation and upgrading, there is a clear need to raise the productivity and opportunities in non-leading areas.

However, for the resources to be deployed effectively, firms in those locations need to have the capacity to absorb and use the technologies. The approach has to adjust to the capabilities on the ground. This includes not only the firms, but also the capabilities of the agencies trying to assist them.

Policy approaches should not be attempting to equalize activities across locations. Instead, they should be about expanding opportunities across locations, enabling more firms in more locations to upgrade. The evidence points to more effective ways of doing this. These include focusing on removing barriers for operational technology adoption, as well as on experimentation with sector-specific interventions targeting deployment of new technologies. Experimentation linked to markets will provide key feedback as to what should be scaled up (OECD, Going Digital 2019).

## What to do?

### Link the choice of policy instruments to firms' capabilities

Accelerating the adoption of operational technologies among SMEs means that policies will need to account for the heterogeneity of firms' capabilities, which will require that countries need to be equipped with a set of policy instruments to match these varying capabilities. Firms digitize at different speeds and have varying internal capacities. Smaller firms tend to have both lower internal capacities and fewer resources to improve them than larger firms. Both the stage of digitization and internal capacities of a firm will impact the type of support required for adoption. Moreover, technology is multidimensional and can be applied to both business functions (such as marketing, customer management, and human resources) and production functions (such as supply chain management and automation), and upgrading these different functions also often requires different types of support.

National policies and strategies that focus on building internal firms' capabilities play a critical role in SMEs' ability to absorb and adopt operational technologies, and consequently accelerate diffusion. These capabilities include digital skills, managerial and organizational capacity (particularly change management), and the capacity to undertake business R&D. Given the vast number of SMEs in Europe, it is unsurprising that there are significant differences across firms in terms of their needs and capabilities. Some small firms have high management capacities and visionary leadership, but most do not. Some have advanced digital skills, and create and use cutting-edge tools, but many more lack even basic digital skills and use largely analog technologies.

EU member states need to devise policies that navigate this heterogeneity and ensure that their SMEs are able to overcome their informational and capability challenges, and market failures. Some instruments include direct financial support. Grants, equity finance and loans help provide resources with limited upfront inputs from recipients, unless grants require a matching portion. These all assume that the underlying challenge is access to finance. These instruments are fairly straightforward to administer, the biggest challenge being in selecting the participating firms and research institutions.

There are other financial tools, such as tax deductions or loan guarantees, that provide indirect financial support. In the case of tax deductions, these are appropriate less for start-ups than for those already established and seeking to expand. Firms need sufficient revenue streams in place to make tax deductions effective. Tax

#### **BOX 8.8** The robotics research project ECHORD++ supports the R&D and technical needs of manufacturing SMEs

The EU-funded European Coordination Hub for Open Robotics Development (ECHORD++) promotes the interaction between robot manufacturers, researchers, and users to facilitate innovations from lab to the market. It is the follow-up project of ECHORD (European Clearing House for Open Robotics Development, 2009–13), which was installed as an incubator to drive innovation by facilitating the cooperation between academia and industry. ECHORD++ offers research consortia funding to develop robotics technology for real-use cases, and their Robotics Innovation Facilities (RIFs) provide a unique chance to try out new business ideas and make field tests at zero risk. These tools are tailor-made to meet the demand for innovative robotics technologies of the manufacturing industry, mainly SMEs with small lot sizes and the need for highly flexible solutions, and public bodies looking for robotics technology at competitive prices for tender processes. The initiative supports the development of the innovation hubs network.

incentives for R&D as a share of GDP have risen in almost every country in the EuroStat database. The top three are Ireland, France and Belgium, all 0.27 percent of GDP or above, with the Netherlands at 0.15 percent in fourth place, followed closely by Hungary, Austria and the United Kingdom. The EU average is about 0.1 percent of GDP, higher than 0.065 percent in the United States, which is still higher than in China. One risk is that firms have an incentive to overreport what counts as R&D in order to make the most of this incentive, requiring more monitoring and skill on the part of government implementors. Loan guarantees help to lower risk and thus can help a firm to qualify for other sources of funding, or for the guarantor to take the first loss helping keep firms solvent.

Other tools focus on non-financial instruments. Many of these can be very effective, particularly those that help with stimulating demand for the firms' products and in providing complementary advice on the business side of the venture. Some of them can be targeted to specific recipients but many have a public goods nature. Public procurement is an important one, where contract sizes can be significant and provide opportunities for firms to demonstrate their value in ways that could expand interest from the private sector too.

There are also services more closely related to technology infrastructure programs, or quality standards and test services, that can help a larger number of firms improve their performance and win important recognition for meeting recognizable standards on quality. Such certification can be critical for firms seeking to expand their market share, not only domestically but also overseas. Less formal, a number of governments, including at the subnational level, have set up recognition awards or business competitions as a way of selecting which firms to help fund, with the recognition itself of having been selected having important signaling value in attracting customers.

Finally, some innovation agencies offer services closer to business advisory or consulting services. Ones that are particularly effective are those that can combine both financial and non-financial assistance, including help with networking and establishing connections with others in the private sector to support build wider partnerships (Cirera and Maloney, 2017).

## CONCLUSION

New data-driven technologies hold great promise for helping Europe achieve its convergence objectives. These technologies can provide the productivity improvements, and subsequent improvements to living standards, with less high-performing countries and lagging regions needing to catch up with Europe's leading hubs. However, this great promise also carries risk. If laggards are left unprepared for this new wave of digitization, the productivity gains from Industry 4.0 technologies will grow even more concentrated in already innovative hubs, thus exacerbating existing spatial disparities.

New operational technologies are drawing increasingly on transactional and informational technologies in ways that could reinforce the potential for greater inclusion. Meanwhile, much of the attention to date has been on data platforms and on B2C companies where Europe is relatively less competitive. However, the expansion of industrial IoT and B2B platforms could be a growing source of competitiveness for European firms that are leaders in operational technologies. Proposals to facilitate the sharing of commercial, non-personal data could reinforce this, assuming it is done in ways that are aligned with competition principles (i.e., is not done to facilitate collusion). The building of larger pools of data could allow for more innovation and a wider application of operational technologies in areas such as the management of building complexes, or utility or infrastructure systems.

## Note

1. For more on the capabilities' escalator approach see: Cirera and Maloney, 2017. *Innovation Paradox*. World Bank Group.

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## CONCLUSION TO PART III

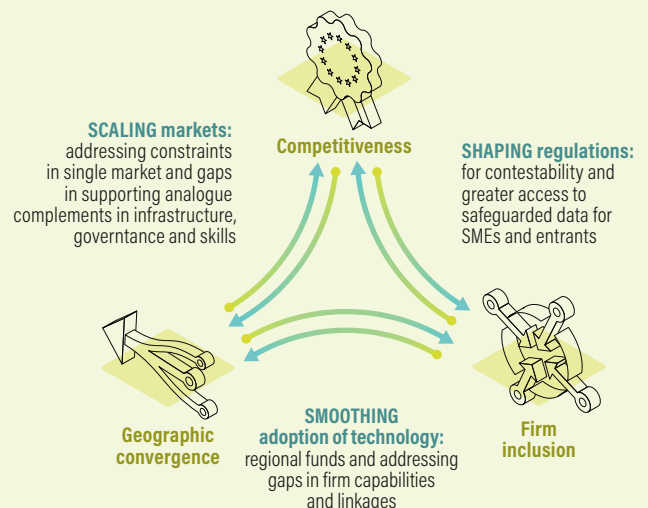
# SPEEDING UP THE EUROPE 4.0 AGENDA: MORE SCALING, SHAPING AND SMOOTHING

Europe 4.0 is achievable. Europe can increase its share in the global economy and have the productivity benefits of new technologies shared widely across firms and locations within Europe. However, if it is to succeed, Europe needs to focus on the following three priorities:

- **Scaling** up digital markets in Europe, by addressing the continued fragmentation in the digital single market and in key supporting services, will be critical in supporting the creation and diffusion of both transactional and informational technologies. But scaling digital markets also needs support from ‘analog complements’. While not new or exciting, this unfinished agenda is incurring dynamic costs, as locations with limited ability to adopt Industry 3.0 cannot build on them to benefit from Industry 4.0.
- **Shaping** the nature of technological opportunities by updating regulations, such as competition policy and approaches to data privacy, will be needed to reinforce opportunities for SMEs and new entrants. Making data portability, interoperability and the right to be forgotten’ operational at scale will be critical for setting these as larger global standards.
- **Smoothing** access to opportunities across locations and types of firms through the allocation and implementation of innovation policies. The commitment to raise R&D spending by 50 percent will need to include sufficient attention to applied research and how to expand technology adoption. Further speed in areas such as operational technologies that may widen gaps across firms and locations will require that much more attention with regard to diffusing technologies and building interfirm linkages in order to expand opportunities.

How is Europe doing? Progress on completing the digital single market is being made – but slowly. Geoblocking and the non-portability of some copyrighted material severely limits the ability for transactional or informational technologies to scale up. At the national level, gaps in the ‘analog complements’, including infrastructure, logistics, skills and governance, also limit the effective scaling up of many markets and limit access to opportunities across Europe. Strengthening

**FIGURE C3.1** Achieving Europe 4.0: Three steps to achieve the goals of competitiveness, inclusion and convergence


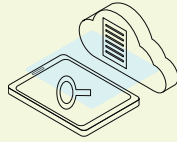
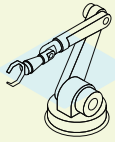


existing start-up clusters would also help more new entrants to scale up in Europe. The larger digital markets will help, as will enabling greater portability of different financial and ownership arrangements.

The EU is successfully *shaping* a value-based approach to the data economy. In Europe, data belong to the people — at least since the adoption of the GDPR. While the European approach may hurt some SMEs and, in the short term, stifle some types of innovation, it nonetheless positions the EU as a global leader in the protection of private data. This can lead to new business models, and is an area where global demand is expected to grow. Already, many companies outside Europe have to adhere to GDPR in order to do business with Europe. Nonetheless, having firms demonstrate how trust in the system can unlock innovation that delivers human-centric services will likely lead to both European global giants, and more opportunities for SMEs and new entrants.

With ambitious goals, Europe has strong mechanisms for smoothing innovation and technology adoption. However, this is still an area where much of the potential remains unrealized. Some European countries are global leaders in operational technologies, although not in informational or transactional technologies. The higher education systems are not well-integrated with industry, and R&D spending, especially in the private sector, is substantially below that of the United States and China. Funds are allocated to encourage the diffusion of technology, but more needs to be done to ensure that resources build on existing capabilities and in sectors with links to (local) market opportunities to improve the effectiveness of these funds.

**FIGURE C3.2** Policy Agenda for Europe 4.0

		 <b>Transactional technologies</b>	 <b>Informational technologies</b>	 <b>Operational technologies</b>
<b>Policy directions</b>		Scaling markets	Sharing commercial use of data	Smoothing adoption in MSMEs and lagging regions
<b>Policy priorities</b>	<b>EU</b>	Complete digital single market and support trade in services	Making competition and data privacy regulations fit for purpose in digital economy	Allocation of R&D and regional funds to build capabilities and links to markets
	<b>National governments</b>	Implementation of the single market Support complements in logistics (e.g., postal systems)	Start-up ecosystems Venture capital markets Digital skills	Support applied R&D, research-firm links
	<b>Subnational governments</b>	"Last-mile" infrastructure, enforcement	Innovation hubs Expand links with local firms and markets	Strengthen firms and governments capabilities to support adoption

Source: Europe 4.0 team.

Note that 'slowing' or 'stopping' are not on the list of proposed policies. Technological change is happening. Europe has to decide how much it wants to embrace this change, and how to prioritize its investments and reforms so that it can achieve its goals. By scaling the size of its digital markets, shaping the rules of the new digital economy to be inclusive, and smoothing access to opportunities, Europe can embrace continued technological changes in ways that help it achieve its triple objective. To speed a resilient and strong recovery to the economic slowdown that the COVID-19 pandemic has brought, the need to address this agenda is now greater than ever. Tackling this agenda now will also give Europe an opportunity to lead in the broader fourth industrial revolution. It should seize that opportunity.



 Federal Ministry  
Republic of Austria  
Finance